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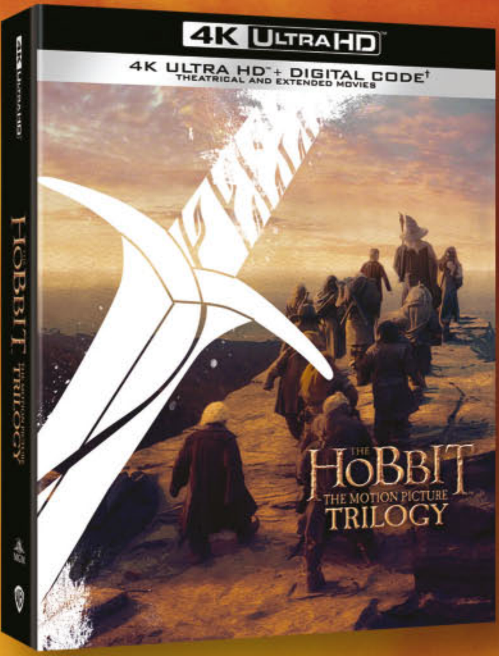
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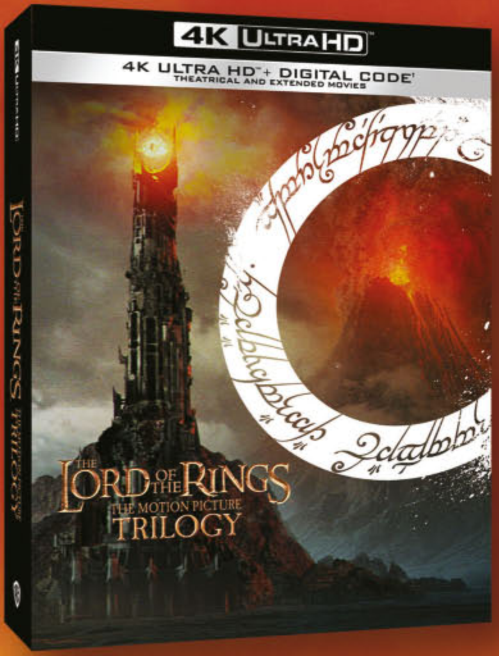
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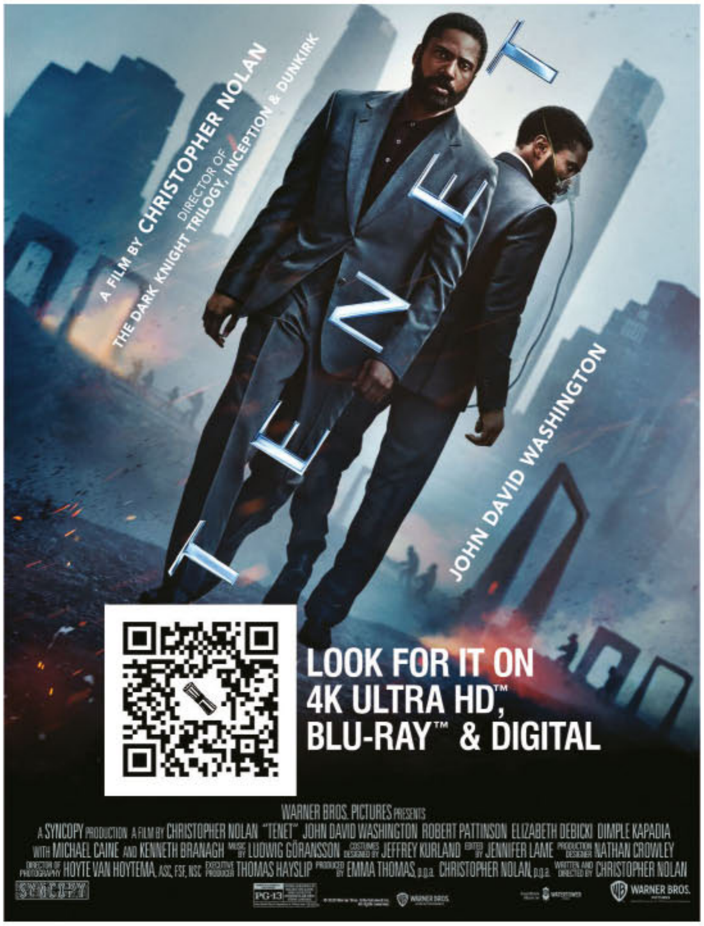
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A RETURN TO NORMALITY

IT'S NICE FOR ONCE to just start writing this and not have any problems. No bad news to share, no major issues to deal with. You know, it's been a long and bumpy year, and one of the weirdest ones I've experienced in my lifetime. From getting my dream job here at *Maximum PC*, to a global pandemic occurring with multiple waves, to being stuck inside for weeks on end, losing budget and pages, and then having to let some of our writers go temporarily, it's been rough for sure. And despite the craziness going on around us right now, it's nice that the mag itself is back into a decent shape, at least as far as budget, content, and page counts go.

I just want to say to all of you who've stuck by us throughout this period, it really does mean the world to us. I know it's not been easy. I don't need to tell you that there's a lot of financial and economic stress out there right now, and a lot of folk have lost jobs, so the fact that you guys and gals out there are still supporting us genuinely means a lot. If I ever meet any one of you in public, I'll buy you a drink! And you can hold me to that. Just look for the hat (although I don't have a beard now).

What does frustrate me, however, is that we are somewhat behind on my ambitions on the mag revamp. Content is about where I want it now, but the benchmarking platforms have been delayed, simply due to the fact that we don't have access to our main offices still. In fact Future's looking at relocating the New York offices entirely, so it might be some time until we find a proper new home, and of course, one that's safe to return to.

But enough moaning, how are things looking? And what's the latest scoop in this issue? Well this time around we're taking a look at building the ultimate $600 office PC, complete with an upgrade path for if you want to push it a little further. On top of that, we've pinched Jarred from *Tom's Hardware* once again to give us the lowdown on AMD's latest Zen 3 architecture, debuting with the Ryzen 5000-series processors. We've also got an excellent eight-page feature on setting up your own Jellyfin media streaming server (an impressive alternative to Plex), and Neil Mohr has the lowdown on the state of virtual machines in 2020, and what you can do at home to emulate everything from Windows 95 and beyond.

Outside of the world of features, I got my hands dirty and transplanted my Hydra Mini work PC into the latest Razer Tomahawk ITX case, Dave shows us how to finally get started sleeving power supply cables from scratch, and Ian relives his shop-class years, building his own Raspberry Pi-based birdbox. We've also got a ton of reviews (including the RTX 3090 and Samsung 980 Pro), news columns, and we've even tweaked Lab Notes (let me know what you think). Couple that with some kick-ass game and software reviews, blueprints, and an opinion piece from *Tom's Hardware*'s Editor-in-Chief, Avram Piltch, and I hope this is an issue you don't forget.

As always, stay safe out there!

Zak Storey

Zak Storey is Maximum PC's *editor and long-time staff member. He's been building PCs since he was 10, and is more than capable of butting heads with the biggest names in tech.*

↘ submit your questions to: comments@maximumpc.com

THE NEWS

AMD Does It Again

Zen 3 gives Team Red another big jump in performance

BY THE TIME you read this AMD will have officially launched its Zen 3 processors. It’s been less then four years since it launched the first Zen-powered chips, and the rate at which they have been improving has been startling. Zen 3 will offer about a 19 percent improvement in IPC (Instructions Per Cycle) on Zen 2. This means AMD has managed to scale the design faster than any other processor in the last 20 years.

Zen 3 is a ground-up redesign that AMD says will finally beat Intel at single-threaded gaming, the one area where the Blue Team always won. There are four initial chips, spread neatly across the market. Top of the pile is the $799 Ryzen 9 5950X with 16 cores, a base clock of 3.4GHZ, and a boost of 4.9GHz. Below this is a 12-core, 3.7GHz Ryzen 9 5900X at $549; the eight-core, 3.8GHz Ryzen 7 5800X at $449; and lastly the six-core Ryzen 5 5600 X running at 3.7GHz. The new Ryzen 9s have 64MB of L3 cache, while the lesser chips have 32MB. All bar the 65W 5600X have a TDP of 105W, and although TDP figures became detached from reality a while ago, these are clearly power efficient. See page 30 for a deeper dive under the skin of the Zen 3 architecture.

As with any new chip there are early benchmarks, often run on engineering samples, and some bold claims from AMD. The 5950X, it says, beats the Intel Core i9-10900K at almost everything, which isn’t too surprising: Intel has nothing equivalent, its desktop chips top out at 10 cores. The new 5900X still manages to beat the i9-10900K at gaming, by “impressive” margins. At 1080p, AMD cites superiority across the whole range. Unofficial benchmarks back up these claims; Zen 3 is fast.

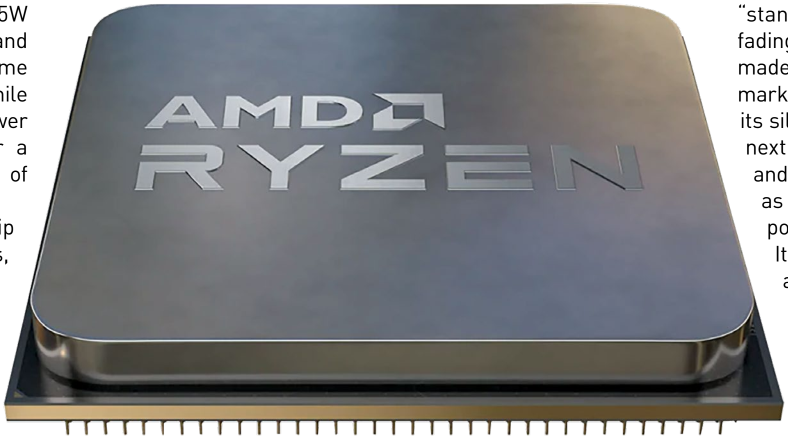
The 5000 series will be supported on 400-series mobos, given a suitable BIOS update, which is good news for upgrading. AMD says you’ll get 26 percent more performance out of a 5900X over a 3900X.

AMD is having a good year financially. Its 3rd-quarter results, helped by the imminent console launches, have seen a revenue jump of 56 percent over last year, with a similar hike in profits.

Before we get too carried away, Intel isn’t doing nothing. There may be no new chips this year, but by next spring we will see the first Rocket Lake chips, and Intel has been teasing us with some details—or rather it has confirmed pretty solid rumors. When either company has a launch, the other puts some form of announcement out to deflect attention.

Rocket Lake will use Cypress Cove cores, a development of Willow Cove built using a 14nm process. This is the first time a mainstream desktop chip hasn’t used something derived from Skylake since 2015. Memory speed has moved to DDR4-3200, faster than Comet Lake’s DDR4-2933. It’ll have the new Xe graphic engine, and will be the first Intel chips with PCIe 4.0 support. There are “up to” 20 lanes, so you can hang a fast SSD off the processor lanes and still have 16 left for a graphics card, should you need that much bandwidth. The core count tops out at eight, as we expected. This boils down to a “double-digit” IPC gain. Some sources have this as being just 10 percent—good, but perhaps not good enough. If the Zen 3 chips make good on the promises, Intel is going to be second best across the board.

The 3rd generation of the Zen architecture looks set to give AMD the world’s fastest desktop chips across the board.



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There is one card Intel can always play—it can be cheaper. The 5000 series has added about $50 to the cost of going AMD and gives some clear water between the two, which is ironic, as being cheaper was always one of AMD’s strengths. It may offer more per dollar, but the dollars still count. Intel also has its HEDT X-Series chips, including the 18-core i9-10980XE, but these involve a specialist mobo, expensive quad-channel memory, and don’t make the amazing gaming machines you might expect. Put simply: Intel currently has no effective response to AMD apart from cutting prices.

AMD has been on a roll since the original Zen, and has managed to maintain the momentum. Going AMD used to be seen as a slightly risky choice, moving away from the “standard” of Intel. That is fading fast: The company has made solid growth for years, market share is climbing, and its silicon now graces both the next generation of Microsoft and Sony consoles, as well as some of the world’s most powerful supercomputers. It has moved from being a slightly odd choice for enthusiasts, to being an actual, legitimate world player. **–CL**

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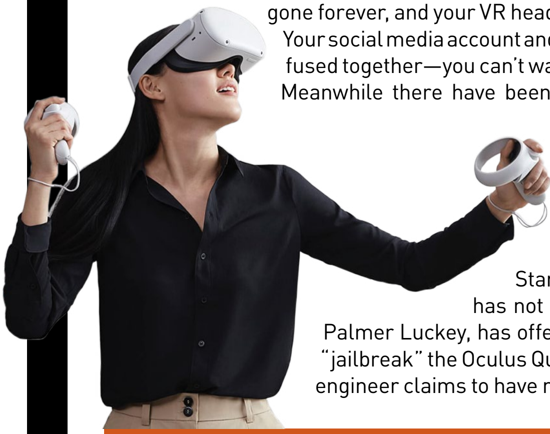

THIS SUMMER FACEBOOK MADE a Facebook account mandatory for users of Oculus VR sets. Now it transpires that if you delete your Facebook account, your Oculus games are gone forever, and your VR headset is an expensive conversation piece. Your social media account and your VR game accounts are irrevocably fused together—you can't walkaway from either without losing both. Meanwhile there have been reports of a good number of Oculus Quest 2 owners having their Facebook accounts disabled when trying to create or link to them, leaving bricked headsets. An automated message claims that the accounts didn't meet Facebook's Community Standards. Facebook's handling of Oculus has not won it many friends. Oculus's founder, Palmer Luckey, has offered a cash reward to anybody that can "jailbreak" the Oculus Quest 2 from its Facebook links. A Mozilla engineer claims to have managed it. **–CL**

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THE 10,000 PPI SCREEN

OLED tech offers unparalleled pixel densities

RESEARCHERS AT STANFORD, working with Samsung, have developed a new type of OLED screen boasting 10,000 pixels per inch or more. Currently even the best displays can't reach 1/10th of this. The technology borrows from work done on solar panels, and uses extra layers: One reflective, and one termed a "meta-surface." This has a grid of tiny (100nm wide) pillars, and clusters of these are used to control the color of each pixel. The light bounces between two silvered layers before being emitted. The obvious use is for VR displays, where the screen is so close to your eyes that the lines between pixels become visible. At more reasonable viewing distances the advantages are less obvious. This is still a proof of concept research project, but Samsung has reportedly started work on production versions. **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

✓ **CHROMEBOOKS UP 90%**
One effect of education moving online in a big way has been a huge surge in Chromebook sales, 90% up year on year.

✓ **POTATO DOOM**
Someone's played *Doom* on a TI-84 graphing calculator using a large potato battery array.

✓ **PCIE 5.0 FIRST TEST**
Intel and Synopsys have run an "interoperability" test for PCIe 5.0. It's expected to reach mobos late next year or early 2022.

TRAGEDIES

✗ **CRUCIBLE IS DEAD**
Amazon has pulled the plug on the online PvP game after six years of development.

✗ **AMPERE DELAY**
The big-memory version of the RTX cards won't be here anytime soon—GDDR6X production difficulties apparently.

✗ **ANOTHER VR CAUSALITY**
Google has finally killed Daydream VR. Strapping a phone to your head wasn't a suitable VR solution after all, it turns out.

THE DOJ TAKES ON GOOGLE

It's accused of "aggressively using its monopoly"

THE DEPARTMENT OF JUSTICE has filed an anti-trust lawsuit against Google, the largest case since Microsoft found itself in hot water over 20 years ago. The accusation is that Google's search and advertising "empire" is against federal anti-trust laws. Google has nearly 90 percent of the search market. This market dominance was achieved, according to the DoJ, by "problematic" business practices. These include simply paying companies large amounts to be the default search engine. Google's reach has enabled the company to enrich itself through advertising, strengthening its grip on the market, making it tough for competitors, stifling innovation, and reducing consumer choice.

This isn't the first time Google has been in the DoJ's firing line. A case in 2012 was called off. This time, we assume, the DoJ is better prepared. The DoJ is not asking for Google to be broken up, as it had in the Microsoft case, but rather asks for "structural relief," which could include the selling off of parts of the business, and the retreat from some sectors. It claims that "For the sake of American consumers, advertisers, and all companies now reliant on the internet economy, the time has come to stop Google's anticompetitive conduct and restore competition." Google has naturally rejected this conclusion.

In an age where many people use the internet as their primary source of information, control of what appears when you search is pivotal. And when it is overwhelmingly in the hands of one company you can understand the unease the DoJ represents. Microsoft lost its case, although it successfully appealed against the original (rather drastic) ruling that would have seen it broken into two halves. It had to open up a little, which ironically helped Google at the time. Will Google manage to do the same? **–CL**

WINDOWS FALL UPDATE

20H2 update goes live

WINDOWS 10 is in the midst of its annual fall update, 20H2 in the company's new naming system. As ever the update will initially receive a limited distribution. At the time of writing it is still an optional update, so you need to manually check for updates to trigger the installation. Over the next few weeks it'll be rolled out to more systems, until your automatic update will insist on it.

The biggest new feature is that 20H2 will include the Chrome-based Edge browser for the first time. This now includes a price-comparison tool, so when you search for a product it'll bring up the best prices available. You can also navigate within Edge using Alt-Tab to cycle through tabs.

The Focus Assist feature receives a welcome tweak too. It can prove annoying when playing games, by popping up and telling you it won't be popping up, then it pops up to show you what you missed. These have been disabled by default. Microsoft has also tweaked the Start menu again; now you have a partially transparent menu with theme-aware tiles, so the backgrounds will be light or dark to match your Windows theme.

The "Display" section of Settings now enables you to change your monitor's refresh rate. Control Panel is slowly being phased out, and this update removes the "System" section, which now redirects to the Settings app. Control Panel is hidden away in Windows 10 anyway, and most (but not all) features are available through the Settings menu.

The Your Phone app has been expanded with more features for Samsung phones, and you now have automatic tablet-switching modes. And that's about it, apart from minor tweaks and bug fixes. This update is focused more on stability, and a little polish. We can expect a more comprehensive update with next spring's 21H1 update. **–CL**

Superconductivity at Room Temperature

Researchers have discovered a material capable of superconductivity at practical temps—59F. Superconductivity enables an electrical current with no resistance, which opens the door to all sorts of wonders previously the realm of science-fiction. It is one of the great hopes of science to create a practical superconducting material. The new material, made from carbon, sulfur, and hydrogen, was created on a diamond anvil, and a laser was used to break down the sulfur bonds. Exactly what the team has made remains a mystery, as the anvil prevents closer examination. Why the anvil? Because the material requires 2.5 million atmospheres of pressure to work, which is something of a problem. **–CL**

Minecraft Requires Microsoft Account

From the start of next year if you want to play *Minecraft* you'll need a Microsoft account. Currently there are two ways in, through Mojang's Java edition, and Microsoft's Bedrock edition, but now every Java player will have to create a Microsoft account, which may mean a new username. The company cites security improvements as the main reason behind the move, and it is to implement two-factor authentication, something people have actually been requesting for years. Thankfully PvP and modding in the Java edition remain unchanged. **–CL**

The new Radeon 6000-series puts AMD's card right back into the fight.

Big Navi Lands

AMD'S BIG NAVI, the RDNA 2 architecture, is finally here, and for the fist time in about a decade AMD is gunning to be the fastest card. There are three initial models: The RX 6800, 6800 XT, and 6900 XT. All carry 16GB of GDDR6 RAM, and 128MB of Infinity Cache.

AMD set itself some big goals for its RDNA 2 architecture, employing what it had learned from Ryzen. A lot of work was done optimizing the cache system, and performance per watt, which is said to be 50 percent better than RDNA. It has also included hardware ray-tracing for the first time, with one RT accelerator per CU. The results, even if we have to rely on AMD's claims and bar charts for now, are impressive. The RX 6800 XT was shown to be comparable with an RTX 3080 at 4K and 1440p, the two were within spitting distance running the 10 AAA titles used as benchmarks. The RX 6900 XT similarly does well against the RTX 3090 at 4K. The RX 6800 was compared to an RTX 2080 Ti, the RTX 3070 not being available yet—and naturally it managed to be slightly better.

If you couple the new cards with Ryzen 5000-series chips and 500-series boards there's an extra treat, thanks to Smart Access Memory. Which will give between a two and eight percent performance bump. You also have a one-click overclocking mode called Rage Mode, which squeezes the processors even more. Next issue, when we have the real thing in our clutches (maybe), we'll see just how the 6000-series pans out. Launch events are always enthusiastic affairs, that said Is there a new champion? We'll see, but AMD has certainly brought a big stick to the fight. **–CL**

© MICROSOFT, AMD

Jarred Walton

TECH TALK

Infinity Cache Changes The VRAM Paradigm

IF YOU CHECK OUT OUR DEEP DIVE into AMD's Zen 3 architecture, it's clear AMD has a new-found love for cache. Reworking the L3 cache on Zen 3 appears to be paying dividends when it comes to CPU performance, but AMD is going a step further with Big Navi, adding what it calls the Infinity Cache, with 128MB of basically L3 cache to reduce bandwidth contention.

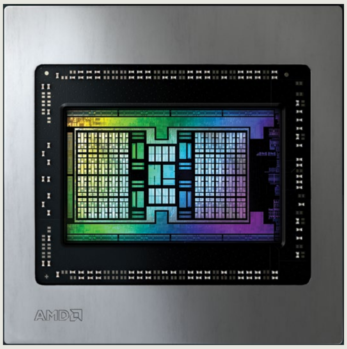
Officially, the chip is Navi 21 and will show up in Radeon RX 6900 XT, 6800 XT, and 6800 GPUs. But taking a cue from the enthusiast community, AMD has adopted the name Big Navi. And it really is big.

Big Navi contains 26.8 billion transistors, which is just five percent shy of Nvidia's GA102 chip. But the way AMD and Nvidia are using those billions of transistors is very different. AMD hasn't revealed the official die size (we estimate it's around 535mm square), but looking at the die shot, the Infinity Cache occupies about 17 percent of the total chip area—it could be more, but the provided die shots often have artistic interpretations, so there's a margin of error.

To put that into perspective, all of the 80 compute units (CUs), which are primarily responsible for the graphics computations, only occupy about 31 percent of the die area. Video interfaces, memory controllers, hardware codecs, texture units, ROPs, and other elements make up the remainder of the die. But the ratio of area used on cache versus other functional blocks is very much skewed in favor of cache compared to other GPU architectures.

Why would AMD use such a big cache? Based on early performance figures from AMD, it's a major part of what will allow Big Navi to compete with Nvidia's Ampere architecture. We haven't had a chance to test Big Navi yet, but even if it's not quite as good as initial results indicate, it's more competitive than the paper specs suggest.

Radeon RX 6800 XT as an example comes with 72 CUs and 4,608 shader cores, compared to the RTX 3080's 68 SMs and 8,704 shader cores. AMD does clock its chip a bit higher this round, with a game clock of 2,015MHz compared to Nvidia's boost clock of 1,710MHz, but that's still theoretical compute performance of 29.8 TFLOPS for the 3080 vs. just 20.7 TFLOPS on the 6800 XT. What's more, AMD is using a relatively paltry 256-bit interface with 14Gbps memory, providing the same 448GB/s of bandwidth as current RX 5700 XT cards—though AMD does double-down on the VRAM capacity by moving to 16GB. RTX 3080 has 760GB/s of bandwidth.



The Infinity Cache is all the teal-colored area at the top and bottom.

© AMD

On paper, then, Nvidia offers over 40 percent more compute and 70 percent more bandwidth. And traditionally Nvidia has made better use of both in its GPUs, so we would expect this to be a landslide victory for Nvidia. Except, the Infinity Cache radically changes expectations.

128MB is large enough to easily hold several copies of a 4K frame-buffer. That means a lot of the z-buffer and frame-buffer accesses will skip the GDDR6, and AMD claims the effective bandwidth thanks to Infinity Cache is 117 percent higher than on Navi 10. That's the equivalent of 948GB/s, which suddenly makes AMD's chips look far more competitive.

The verdict is still out on ray-tracing performance. AMD says the hardware ray accelerators (RAs) are 10 times faster than doing ray calculations via shaders, which is similar to Nvidia's claims with Turing. But Ampere is supposed to be about 70 percent faster per RT core when it comes to ray tracing. Nvidia also has DLSS 2.0 used in several games, with more on the way. AMD's working on FidelityFX Super Resolution, which appears to take a similar approach, but it won't be available for games for months.

Still, that big L3 cache is a wild card that can change efficiency and performance in lots of ways. Latencies are reduced, efficiency improves, and potentially we end up with AMD 300W GPUs matching or exceeding the performance of Nvidia's 320W and 350W GPUs. We'll review Big Navi next month.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

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Avram Piltch

OPEN SOURCE

Why Every PC Builder Needs Some Pi

THERE'S NOTHING QUITE LIKE the thrill of building a computer: The hours spent carefully positioning boards, plugging in wires and routing cables, all leading up to the moment of truth—power on! Unless you do it for a living, you can only experience the joy of putting together a PC so often. But there's an equally exciting way to scratch your building itch: Raspberry Pi.

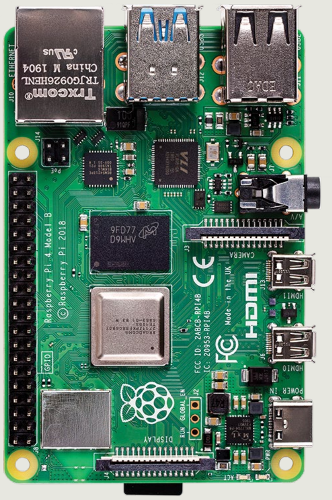
Launched in 2012 and now in its 4th major generation, Raspberry Pi is the inexpensive ARM-powered, single-board computer that will change your tech life. The Raspberry Pi 4 has enough quad-core performance to do web surfing, productivity work and programming, but if you buy one expecting to use it as a substitute PC, you'll be disappointed.

What makes a Raspberry Pi compelling is its ability to power all kinds of project you wouldn't or couldn't use an x86 PC for. Want to build a Game Boy-sized console emulator powered by Intel or AMD? Good luck cramming your micro ITX mobo and PSU into the case. How about an IoT device to alert you when you're out of toilet paper? To what PC mobo will you wire the distance sensor you need?

You can use a Raspberry Pi for everything from a home media server to a smart Geiger counter to a high-powered robot. The Raspberry Pi's 40 GPIO (general input/output) pins give it the ability to interface directly with lights, motors, and sensors, or to use a huge ecosystem of add-on boards called HATs (hardware attached on top) that won't work with a PC.

The Raspberry Pi is also really good at doing emulation. You can easily build a retro arcade cabinet or console, and by using a popular emulation platform like RetroPie, you can run games that originated on a smorgasbord of platforms, from old-school arcade machines up to the Nintendo 64.

> What makes a Raspberry Pi compelling is its ability to power all kinds of projects



The Raspberry Pi 4 starts at $35 for the 2GB model.

© RASPBERRY PI FOUNDATION

Though there are more than 20 operating systems that run on Raspberry Pi, the most popular is the official platform: Raspberry Pi OS, a fork of Debian Linux. Because it runs Linux and uses very little power (a max of 15 watts, but usually no more than 7.6 watts under load and 3.4 at idle), the Pi makes a great server that can get juice from a typical USB charger or sip battery power all day from a standard power bank.

There are other single-board computers on the market, some of which are blatant clones with names like Banana Pi and Orange Pi, but what makes Raspberry Pi such a success is the support of a huge community that not only answers questions on forums, but also writes tons of open-source software for it. The Raspberry Pi Foundation, the organization behind the board, has sold more than 30 million units, and Reddit's /r/raspberry_pi alone has 2.1 million members.

You might ask: "Do I need more devices?" Living your best tech life isn't about raw utility, but the thrill of learning and problem-solving, the same you get from a challenging PC build but on steroids.

Best of all, if you're a parent, you can use Raspberry Pi projects to learn alongside your kids. My eight-year-old and I have been building robots and retro systems for more than a year, and now he can program in Python, the most popular language for Pi projects, while other kids his age are still learning block-based coding. That's not bad for a computer that costs less than some mice!

Avram Piltch is the Editor-in-Chief of Tom's Hardware (www.tomshardware.com) where he hosts the Pi Cast, a weekly Raspberry Pi Podcast.

DOCTOR

THIS MONTH THE DOCTOR TACKLES…

> Alienware 240Hz
> Move Program Folders
> RAM Upgrade

Broken Alienware?

Hi Doc, my monitor is an Alienware 25 and it says it will display 240Hz, but if I go to my settings to change it to 240Hz the screen goes black and then nothing happens until it reverts automatically to 60Hz. Do I need to have an Nvidia graphics card, or can I use it with an AMD graphics card?

–Gregory Muenzer

THE DOCTOR RESPONDS: There are two versions of the Alienware 25 monitor, and which model you have will determine which card you'll need. The G-Sync version (model number AW2518H) requires a G-Sync compatible card, which basically means GeForce GTX 650 Ti Boost or higher. If you have an AMD card—any Radeon RX model—you'll need the FreeSync version (AW2518HF). One final consideration: 240Hz mode is only available through DisplayPort, it's not supported through HDMI, so make sure your card has a DP 1.2 or better.

If you have the G-Sync model with a compatible Nvidia graphics card, open Nvidia Control Panel and click "Set up G-SYNC" under "Display." Check "Enable G-SYNC" and click "Apply." Then, verify the AW2518H is the primary display under "Set up Multiple Displays," select "Manage 3D settings" under "3D Settings," and click the "Monitor Technology" dropdown to check G-SYNC is the selected feature.

240Hz support requires G-Sync or Freesync.

Still struggling with G-Sync? Visit http://bit.ly/MPCblurbusters for a guide to setting up and optimizing it.

Move Programs to New Drive

I want to know how to move my OS. I've upgraded from a 2TB Western Digital Black SATA HD to a 6TB WD Black drive.

I want to move Windows 10 Home x64 to an SSD all by itself and keep my program files on a separate 6TB drive with Windows pointing to the data drive. Is it possible to do this and not have to reinstall all my programs?

I asked the tech support department for WD and Acronis (I used their drive clone software for my HD upgrade). Both tech support departments replied with responses that sounded like they were reading from a script, basically saying, "Yes, you can clone the old drive to the new drive very easily." I restated the original question and both companies skated around the question with the same reply. If it is possible to do this, what is the best-size SSD to use for Windows 10 Home x64? **–William Heckel**

THE DOCTOR RESPONDS: It's technically possible to split off your programs and Windows without reinstalling everything, but the Doc isn't a fan of doing so—apps and Windows are tied together so tightly you might as well keep everything on the same partition. Now that 500GB SSD drives can be had for around $50, you should find that it leaves you ample room for Windows and most apps.

What you can and should do is keep your personal files on a separate partition, so if something happens to your Windows partition they're still accessible. Step one of the process is to partition your current 6TB drive in two, then transfer across all your photos, documents, files, and so on to the new partition. Do this by opening File Explorer to "This PC," right-clicking each of your user folders—Desktop, Documents, and so on—in turn and choosing "Properties → Location" tab to move it to your newly created partition. This ensures that Windows knows where the files have been moved to. Click "OK," the files will be moved (not copied) to free up space on your Windows partition.

After you've moved everything across, your Windows partition should be much smaller, but if it's still

↘ submit your questions to: doctor@maximumpc.com larger than your SSD drive, here's the bit you'll be most interested in: Moving apps and programs without reinstalling them. With apps installed through the Microsoft Store, navigate to "Start → Settings → Apps," click on an app, and use the"Move" button to switch the drive it's installed on.

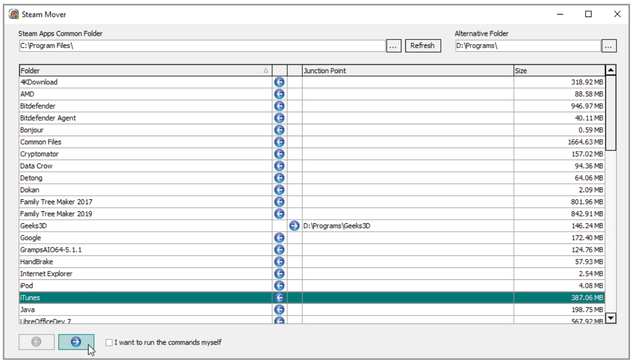
Most programs can't be moved this way, which is where a free tool (Steam Mover, www.traynier.com/software/steammover) comes to the rescue. The app moves selected programs across to your data partition, then creates special shortcut links called "junction points" to fool Windows into thinking they're still on your C drive.

Steam Mover is incredibly easy to use: Launch the program as an administrator and click "..." next to the "Steam Apps Common Folder" shortcut to select your Program Files folder, which is where most of your programs should reside. If you're running a 64-bit version of Windows, programs are mostly split between here and the Program Files (x86) folders, so after moving programs from one folder, select the other and repeat the process.

Now click "..." next to "Alternative Folder" to choose a folder on your data partition. Finally, using the Size column to help identify the largest programs, Ctrl-click on the program(s) you wish to copy across. Once selected, click the blue right-facing arrow button at the bottom, and the files will be transferred. All actions can be undone later.

Focus on transferring as few programs as you can get away with—they'll launch and run more slowly than those on your SSD, so place less frequently used programs on your data partition.

The final step of the process will be to clone your Windows partition to the new SSD using a suitable tool, making sure it copies the boot partitions as well as Windows itself. Once done, reboot, making sure your PC is configured to boot from the SSD—once back into Windows, which should boot more quickly now you're on the faster SSD, you should be able to remove the original Windows partition from your 6TB drive and reallocate the space to your data partition or keep it separate (perhaps as a backup drive for your main Windows partition).



Folder			Junction Point	Size
4KDownload	←			318.92 MB
AMD	←			88.58 MB
Bitdefender	←			946.97 MB
Bitdefender Agent	←			40.11 MB
Bonjour	←			0.59 MB
Common Files	←			1664.63 MB
Cryptomator	←			157.02 MB
Data Crow	←			94.36 MB
Detong	←			64.06 MB
Dokan	←			2.09 MB
Family Tree Maker 2017	←			801.96 MB
Family Tree Maker 2019	←			842.91 MB
Geeks3D		→	D:\Programs\Geeks3D	146.24 MB
Google	←			172.40 MB
GrampsAIO64-5.1.1	←			124.76 MB
HandBrake	←			57.93 MB
Internet Explorer	←			2.54 MB
iPod	←			4.08 MB
iTunes	←			387.06 MB
Java	←			198.75 MB
LibreOfficeDev 7	←			567.92 MB

☐ I want to run the commands myself

Steam Mover moves apps to another drive—no reinstall required.

© STEAM MOVER

Potentially Tricky RAM Upgrade

I built my current system last summer around an MSI MEG Z390 ACE mobo and a Noctua NH-D15S fan with only the original (inside) fan fitted. I currently have two G-skill Trident Z RGB 8GB DDR4-3200 sticks in the "proper" slots. Is it possible to add two more sticks without removing the Noctua tower first to do it? I know they will fit below the fan if I can get them in there. It seems like there's enough room to slip it in below the fan, but I don't want to have to remove that fan to do it. My system is performing fine now, but I'd like to do a bit more future-proofing. **–DocDJ**

THE DOCTOR RESPONDS: Judging from your mobo manual, it appears you've got DIMMs in slots A2 and B2, which leaves the slot closest to the CPU as the trickiest to populate. That said, it looks like there should be enough clearance to get a new RAM stick fitted without too much trouble—although you'll need to temporarily remove at least one stick of existing RAM (the one in slot A2) to give yourself room to fit the new RAM into slot A1 underneath the fan.

In fact, why wait to determine if you'll be able to fit the upgrade without having to remove the fan? Power down your PC, and then open the case, having remembered to take the usual anti-static precautions. Remove the stick of RAM from slot A2, then try fitting it into slot A1 (if it's a bit cramped, consider removing the stick of RAM from slot B2 too to give you more room). Once you've confirmed whether it's possible, simply restore the RAM to the original slots, reboot, and you'll know exactly what to expect when you upgrade your memory.

File Recovery

Hi Doc. I accidentally deleted three SMV files from a flash drive. I recovered the files using Recuva, but they're corrupted. What can I do to recover such corrupted files? The videos are messages I made for my son, and I would like to keep the original files and not just make new ones. Thank you! **–Scott Sherrill**

THE DOCTOR RESPONDS: The key to any data-recovery operation is to stop writing files to the affected drive as soon as you're aware that data has been lost. As soon as part of the deleted files has been physically overwritten with fresh data, your chances of retrieving a non-corrupted file are pretty much zero. File recovery also works better with more commonly used file types rather than niche formats like SMV.

All may not be lost, however: Because it's an uncommon file type (along with the fact Recuva hasn't been updated since 2016), you might find that another tool is better at retrieving it. Two tools to try are EaseUS Data Recovery Wizard (http://bit.ly/MPCeasus), which can recover up to 2TB of data for free, and DMDE Free Edition (https://dmde.com), which is a powerful tool supporting a wide range of file systems.

Why Drive Letter X?

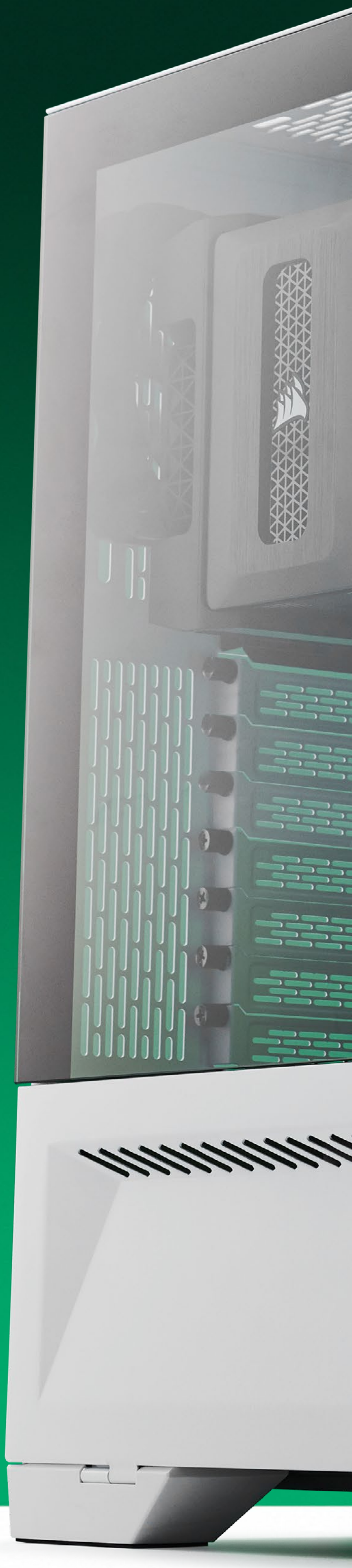
Thanks for your reply to my question (Non-booting laptop, **MPC October 2020**), but you did not answer my question: Namely what causes the HDD drive to change from C: to X: on booting? **–Manuel Trucco**

THE DOCTOR RESPONDS: Apologies, Manuel—the Doc got his drive letters confused in his previous answer. The X: you're seeing on booting into the Windows recovery environment isn't your Windows partition, but a temporary RAM disk created by WinRE to load its own files into. That said, typing c: and hitting Return at this point wouldn't necessarily have taken you to your Windows partition, so first type "diskpart" and hit Enter, then type "list volume" and hit Enter to see what letters the recovery environment had allocated to your drives. In rare cases drive letters may appear to be mixed up where there is more than one volume, but it's all temporary—when rebooted, the Windows drive would have reverted to drive C. Ultimately none of this would have hindered any subsequent attempts to repair your system using the Lazesoft Recovery Disk.

Now that you've restored your daughter's laptop, it's important you take measures to avoid similar disruption and data loss in the future. The Doc recommends taking the time to set up a robust backup system using Macrium Reflect Free (www.macrium.com/reflectfree) to take regular system images of the entire drive to prevent any future disasters. ⏻

Working from home? Here's our straightforward guide to building a solid office PC

OFFICE HOURS



THE HOME-WORKING REVOLUTION might've been a brief bump in the professional road for some of our readers, but many of you might find yourselves settling in for the home office long-haul. Many are simply looking to split their time between the office and home. Either way, there's something to be said for the humble home office PCs across the nation, many of which will probably be getting their first major workout in years.

If you've got an ageing work computer at home, perhaps a chunky Intel-branded tower from 2008 or a laptop that needs to be plugged in constantly, it's time for an upgrade. This issue, we're going to be breaking down the specifics of what makes a good home-working PC, then going through the build process in detail so even the rookie builders out there can follow the process.

First of all, it's got to be affordable. It's one thing to drop $3,000 on a powerhouse gaming rig or 4K video-editing workstation, but if all you want to do with your PC is office work and the odd bit of Netflix streaming, then there's no need to break the bank. We're aiming for a target price in the realm of $500 here, although we targeted that before all the components had been finalized, so forgive us if we ruin that in a few pages.

We're talking integrated graphics rather than a dedicated GPU, a sensibly priced motherboard, and a low-wattage power supply with leeway for future system expansions. We're not going to dabble in RGB or flashy cooling solutions—it's air cooling only here.

Secondly, and just as importantly, this PC needs to be competent at the broad range of office work we're going to throw at it. Sure, none of it's going to be extremely demanding, but we're talking about everything from simple word processing to giant spreadsheets and lightweight graphic-design work. So we'll need a mid-range processor with enough memory to perform at full potential

We won't be slapping a big drive in this either; cloud-based storage is generally a better option for anyone who doesn't need to handle massive media files in the nine-to-five. That said, we won't completely skimp on storage.

The competition here is fierce. Pre-built compact work desktops and all-in-one solutions are common and generally not too expensive, so we need to stay on budget. Later on, we'll break down options for cutting the price down further, as well as upgrading. If our mission is successful, we should have a home office PC that will last for years to come.

STEP-BY-STEP BUILD GUIDE PG 24

PRIME B460M-A
LIAN LI

INGREDIENTS

PART		PRICE
CASE	Lian Li Lancool II	$87
MOBO	Asus Prime B460M-A	$98
CPU	Intel Core i3-10100	$115
CPU COOLER	Corsair A500	$75
MEMORY	8GB (2 x 4GB) HyperX Savage DDR4-3000	$59
PSU	450W Corsair CX450	$58
BOOT DRIVE	Samsung 860 Evo 500GB	$69
OS	Windows 10 Home OEM	$20
TOTAL		$581

PRICES CORRECT AT THE TIME OF PRINTING

MOTHERBOARD

Asus Prime B460M-A

$98

The B460 chipset is the ol' reliable of Intel motherboards, and the Asus Prime B460M-A is a cheap mobo solution that has all the features we'll require, without any costly bells and whistles. We don't need RGB lighting or USB-C support here, just solid performance and a simple layout that will be straightforward enough for rookie PC-builders to work with. The UEFI BIOS is easy to navigate, and Asus's proprietary OptiMem technology helps to improve RAM stability and performance without needing any user input. The rear I/O packs both HDMI and DisplayPort support for our integrated graphics to output video.

IN SEARCH OF INCREDIBLE
ASUS
PRIME B460M-A
EATX12V
LGA1200
PCIEX16
DIMM_B2
DIMM_B1
DIMM_A2
DIMM_A1
HEATSINK_PCH
BATTERY
nuvoTon
LANGuard

STEP-BY-STEP BUILD GUIDE PG 24

CPU

Intel Core i3-10100

$115

The Core i3-10100 is the archetypal budget CPU from the current Intel generation, bringing four cores and eight threads to the party, along with Intel's solid UHD Graphics 630. It's certainly a modest offering compared to some of the powerhouse CPUs and GPUs we love to look at in *Maximum PC*, but for a professional system that needs reliability and efficiency, it's an excellent choice. Intel Turbo Boost technology gives this chip an impressive max boost clock of 4.3GHz, and while those integrated graphics won't be able to handle much in the way of gaming, for streaming video at resolutions up to 4K it should be able to manage just fine.

CPU COOLER

Corsair A500

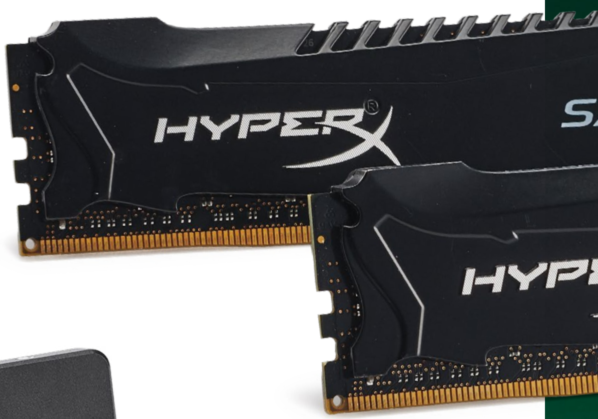
$75

At the time of writing, the A500 has 25 percent off its retail price of $100, making it an excellent deal. It's a lot of money to spend on a cooler, sure, and the Core i3-10100 does come with a stock Intel cooler, so if you're looking to lop some cash off this build then the aftermarket cooler should be the first thing to go. But Intel's stock coolers are pretty mediocre, and given that the 10100 will be handling both CPU and iGPU tasks, we've decided that a beefier cooler will allow for lower operating temperatures and some overclocking headroom. The A500 is a twin-fan beast, one of the biggest air coolers we've seen, so it fits the bill perfectly.

SSD

500GB Samsung 860 Evo $69

Samsung's SSDs are still among the best in the biz—even the older models like the 860 Evo. Half a terabyte of SATA III storage for under 100 bucks was unheard of just a few short years ago, but the 860 Evo is cheaper than ever now, bringing 3D NAND and 500MB/s+ transfer speeds to your PC without breaking the bank. The more SSD technology advances, the cheaper older SSDs become. Given the gap in performance, we imagine it won't be that long before HDDs are rendered entirely obsolete, beyond budget long-term storage uses such as mass data backups and home NAS systems.



SAMSUNG
Solid State Drive

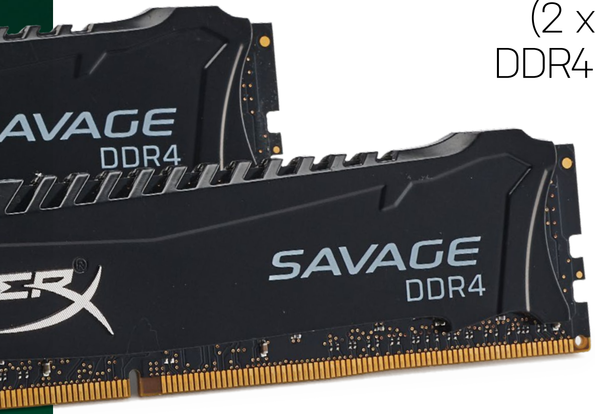
CORSAIR
CX450
CORSAIR

PSU

450W Corsair CX450 80+ Bronze $58

There's no need for a fancy modular power supply here, nor a high wattage. 450W is more than sufficient for this build (our processor's TDP is only rated at 65W, for example) and will allow for some expansion later on if required. Corsair is a trusted brand when it comes to power supplies, and the 80+ Bronze certification guarantees decent energy efficiency for this build. The CX450 is good value at $58: Not the cheapest 450W PSU around, but we'd advise against selecting super-budget manufacturers when it comes to your power supply. If you buy new, the CX450 comes with a five-year warranty from Corsair, covering you for component failure.

STEP-BY-STEP BUILD GUIDE PG 24



RAM

HyperX Savage 8GB (2 x 4 GB) DDR4-3000

$59

With memory prices falling significantly over the last couple of years, 8GB should be considered the new baseline for any system. If you're looking to do anything more demanding than bog-standard office tasks, such as gaming or video editing, 16GB will often be a better option. Higher speeds of DDR4 RAM are also becoming the norm, with 2,400MT/s kits costing fairly similar to their speedier contemporaries. As such, we've chosen a simple dual-channel 8GB kit at 3,000MT/s from HyperX, which should be plenty for the sort of work this system is designed to do. Upgrading the memory later on is always an option, of course.

CASE

Lian Li Lancool II

$87

We have a confession to make: The Lancool II wasn't our first-choice case for this build. When time constraints and deadlines loom, we sometimes have to make quick decisions to get our builds out to your eyeballs on time. You might've been able to figure this out from our choice of motherboard, as this is a chunky ATX mid-tower rather than the more compact mATX case we were hoping to secure. It's still an excellent choice, with a durable metal and glass construction and plenty of space for cable routing and drive mounting. Should you wish to expand storage later, the Lancool II's got you covered.

GETTING DOWN TO BUSINESS

With no unusual features and no graphics card, this is a build that even a novice should be able to complete. Clear some space, gather your components, and let's get to work.

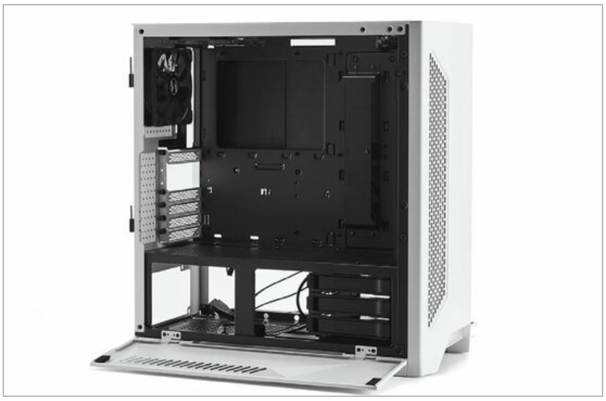
LENGTH OF TIME: **1-2 HOURS**

LEVEL OF DIFFICULTY: **EASY**

1 OPEN SESAME

THE LIAN LI LANCOOL II'S two tempered-glass panels are hinged at the rear but offer no visible handle or push-pins to open them. Instead it has two "wings'" forming the sides of the PSU shroud, which secure magnetically and are hinged at the base of the case. Open both of these using the small handles at the back of the case, swing open the glass side panels, and carefully lift them off their hinges. Replace them in the case box.

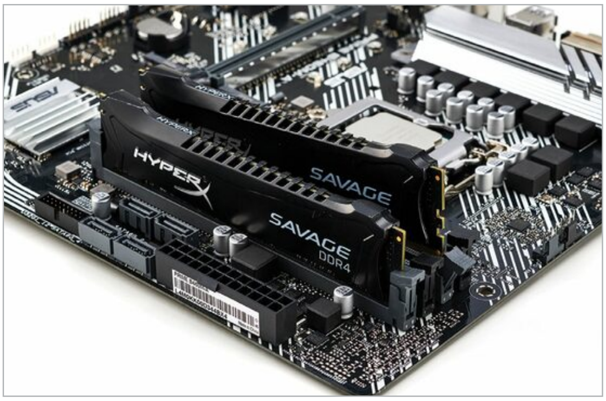
Don't worry about removing the front panel as we're not changing the pre-installed fan at the front, but remove the magnetic dust filter on the top. Finally, remove the two black metal cable shrouds on the rear of the mobo plate. These come off with a single thumbscrew each; set them aside for later.



3 MEMORY MOUNTING

RAM INSTALLATION shouldn't be too complicated. There are two sticks but four DIMM slots. Thankfully, the motherboard has labels printed on it to indicate which slots will be prioritized by the finished system—slots A2 and B2 here; that's the second and fourth slots away from the CPU socket. These DIMMs only have clasps on one end, so release these and then lower each stick of memory into place, lining it up then pushing it down at both ends so it clicks into place and the clasp snaps shut.

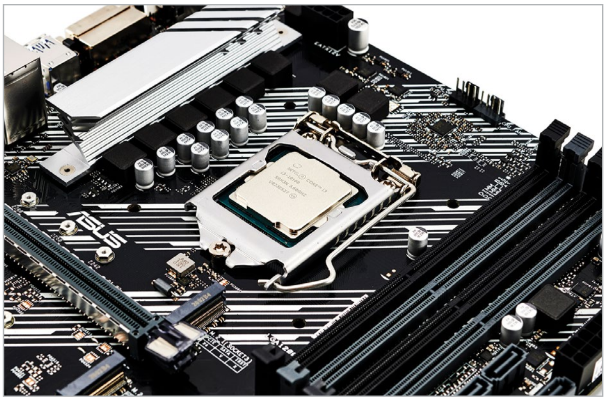
Be gentle when positioning the memory in each slot; the silicon undersides of the sticks can be delicate. Memory upgrades might prove a bit bothersome, as the cooler we're going to install will obstruct access to the DIMM slots.



2 PROCESSOR PROBLEMS

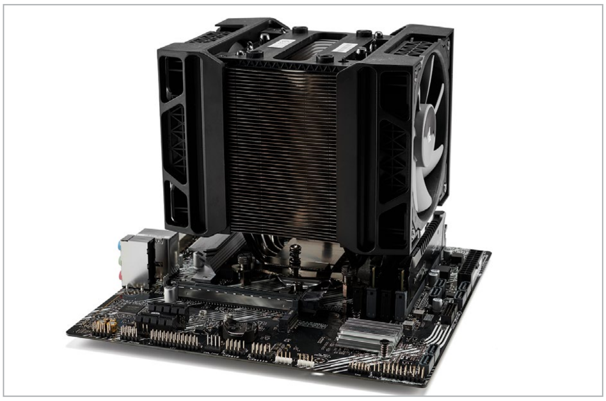
THE CPU SOCKETS on Intel motherboards are less beginner-friendly than their AMD equivalents, but the CPU is still one of the easiest components to install. To open up the bracket, depress and release the metal retention arm from the clasp to the side of the socket, then lift it up so that the metal "teeth" at the end of the socket slide out from underneath the fixed screw and the entire bracket rises up. Drop the processor into the socket, lining it up correctly, then lower the bracket back into position, locking the teeth under the screw and pushing the retention arm back down beneath the clasp.

If your mobo is new, it will have a plastic cover affixed to the top of the bracket. It'll pop off once you re-secure the bracket.



4 DOUBLE TROUBLE

SINCE THIS TWIN-FAN offering from Corsair can be used with different CPU sockets, it comes with its own proprietary mounting solution. Open up the Intel 115x plastic bag for the parts. Fit the large bracket to the underside of the mobo, so it lines up with the four holes around the CPU. Screw in the four 115x standoffs, then fit the two mounting brackets to those using the provided thumbscrews. Remove the pop-off top panel of the cooler block and free the two fan power cables, then fit the cooler over the CPU (mind your fingers on the thermal paste), and secure the two sprung screws using the included long screwdriver. Replace the top panel, and plug the cables into the CPU_FAN and CPU_OPT headers on the mobo.



MAKE IT CHEAPER

We went a bit over budget for this build, but don't worry, there are always ways to trim down the price on any custom-built PC. Our first target here would be the case. As we mentioned earlier, the Lancool II—while great—wasn't our initial choice. A budget mATX case from the likes of Cooler Master or Corsair, without any RGB lighting or tempered glass, shouldn't cost more than 50 bucks. Sure, it won't look as nice as the PC we've built here, but if it's going to be hidden beneath a desk then it hardly matters.

Cutting back on our cooling solution is also an option here, as the Corsair A500 is a relatively expensive air cooler. Using the stock Intel cooler that comes with your processor is always an option, although plenty of budget aftermarket coolers are available for between $20-$40, and these will almost certainly offer better thermal performance. You may also be able to save a small amount of cash by switching out the SSD to a more affordable brand such as Adata or Kingston, and an MSI or ASRock B460 motherboard should let you shave off a few extra dollars.

As always, be wary of brands you haven't heard of when it comes to buying PC components. If a deal seems too good to be true, do a bit of research to find out what people think about the manufacturer in question. Cheap knock-offs are common, and while some budget brands (like PowerColor, ARCTIC, or Rosewill) are generally OK, there are some components that you shouldn't compromise on. When it comes to drives and power supplies, it's best to stick with the household name brands; not only does this ensure quality and longevity, but manufacturers like Corsair and EVGA offer lengthy warranties, should anything go awry.

The Cooler Master N200 doesn't look like much, but it's a straightforward and effective PC case for just 45 bucks.

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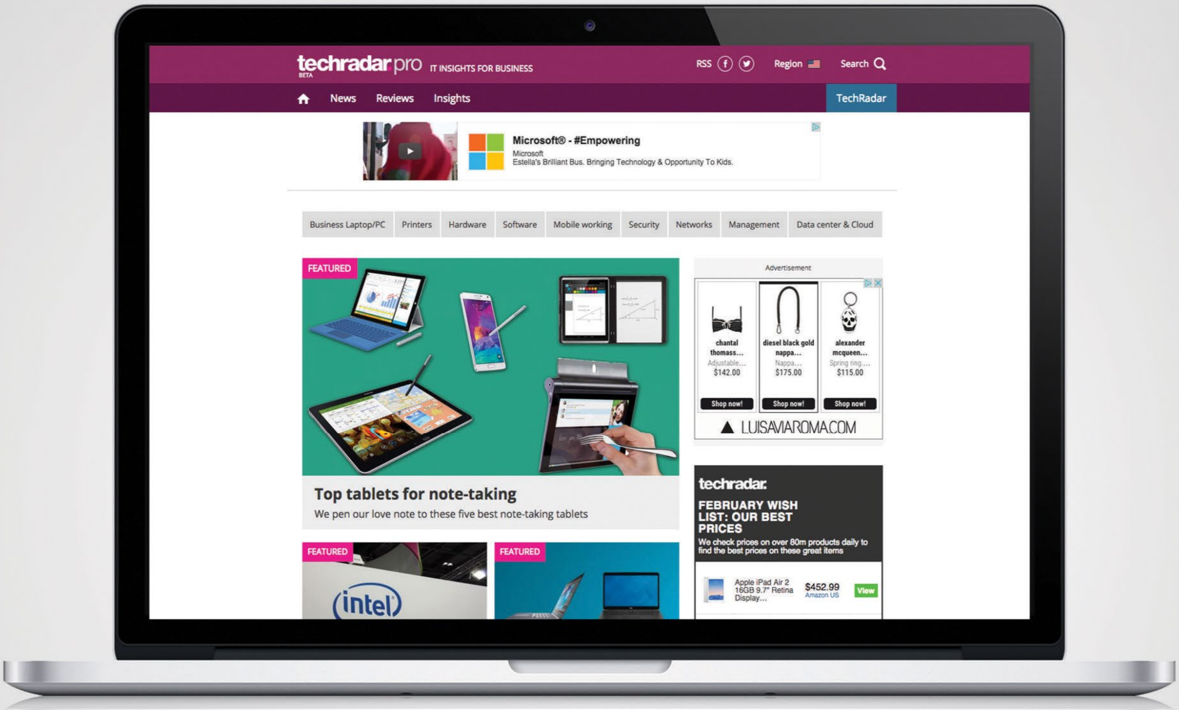
IT INSIGHTS FOR BUSINESS



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5 BOARD STIFF

IT'S TIME TO FIT that mobo! You'll need to move some of the standoffs in the Lancool II, since they're likely to come laid out for a standard ATX motherboard rather and an mATX model like the B460M-A. Using an adjustable wrench, loosen the required standoffs and reposition them so that they'll line up with the holes around the edges of the mobo. Then, place the case on its side and carefully lower the mobo into it, mounting it on the central mounting peg before ensuring that all the standoffs are lined up correctly. When you're confident, use a Phillips-head screwdriver to secure the motherboard at the six mounting points—use a long magnetic screwdriver for this. Also, remove the case fan in the roof of the case by removing its four screws.

6 CLEAR YOUR PLATE

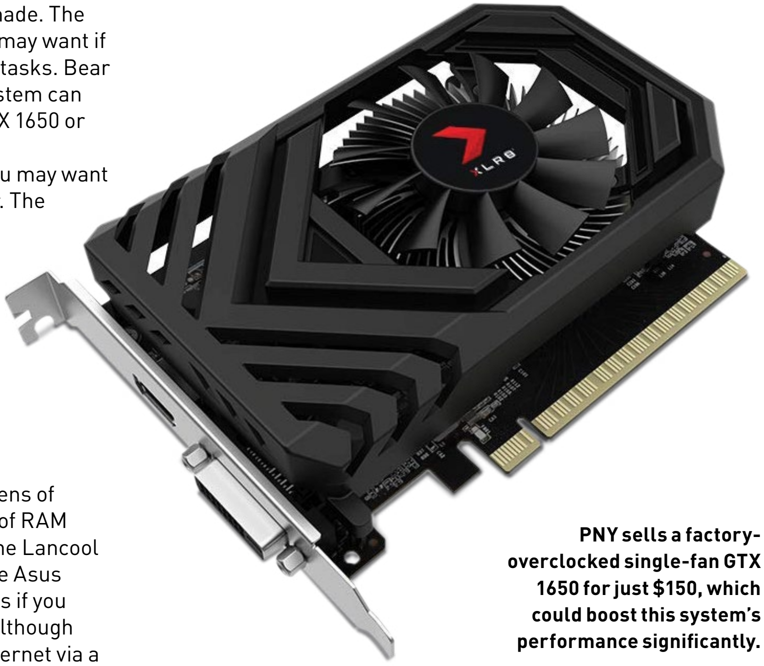
THE SSD MOUNTING PLATE can be found behind the motherboard, secured by a lone thumbscrew. Remove it, and use four of the same screws used to mount the motherboard to affix the Samsung 860 Evo to this slip of metal. Make sure the drive will be pointing downwards once it's returned to the case; when you re-mount the plate and secure it with the thumbscrew, you'll need to connect it to the motherboard using a SATA cable (included in the motherboard box). Given the upright-facing SATA ports on the motherboard, use the cable that has a perpendicular connector on one end, allowing you to more easily bend the cable around and plug it into the mobo. It doesn't matter which of the SATA ports you use here.

MAKE IT BETTER

If you like the look of this system but feel that it's not quite up to the work you want to do, there are improvements to be made. The obvious addition is a dedicated graphics card, which you may want if you need your system to be capable of any 3D-rendering tasks. Bear in mind that without upgrading the PSU and CPU, this system can only support a relatively conservative GPU. An Nvidia GTX 1650 or AMD RX 560 would both be a good fit, for around $150.

If you're not looking for improved graphical oomph, you may want to investigate the potential of a more powerful processor. The Core i3-10300 clocks a little higher than our chosen chip and also has slightly more cache memory, but if you want to see a real improvement then jumping up to the hexa-core i5-10400 or i5-10500 is a better choice. It's worth noting that all of these chips have the same UHD 630 integrated graphics; if you really want better performance from your iGPU, you will need to jump ship to the Ryzen 5 3400G and its excellent RX Vega 11 integrated graphics.

Elsewhere, there are more straightforward upgrades that can be made. If you're the sort who likes to keep dozens of Chrome tabs open at once, upgrading from 8GB to 16GB of RAM might be a worthwhile (and not too costly) adjustment. The Lancool II case has ample room for additional hard drives, and the Asus Prime B460M-A has two M.2 slots for super-speedy SSDs if you need fast file transfers in your day-to-day work. Lastly, although we always recommend connecting your system to the internet via a wired connection, if you're going to need Wi-Fi capabilities for your machine you'll need to select a motherboard with wireless support.



PNY sells a factory-overclocked single-fan GTX 1650 for just $150, which could boost this system's performance significantly.

7 POWER HOUSE

BEFORE INSTALLING the power supply, tuck the front I/O cables out of the way towards the front of the case. You're not going to need all the cables provided, but the non-modular design means there's no way to remove them. You'll need a 24-pin ATX power cable, an eight-pin CPU power cable, and a multi-connector accessory cable. Bundle the rest with cable ties.

Install the power supply at the rear of the case, with the fan pointing downwards, then screw it into place with four of the PSU screws. Route through and plug in the two larger power cables to the connectors on the mobo, and connect the accessory power cable to the SSD and lighting strip from the front I/O cable bundle. Make sure the clasps on the mobo power cables click into place.

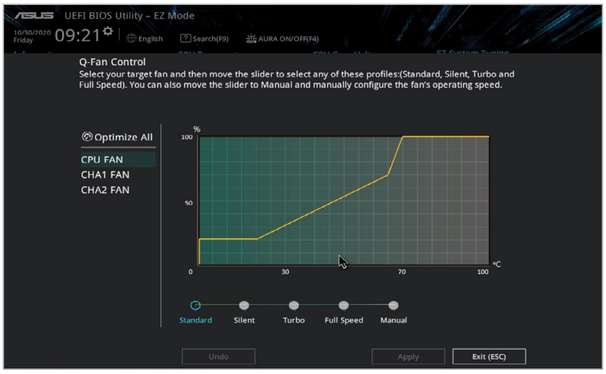
8 SHROUDED IN SECRECY

THERE'S NO APPROPRIATE RGB header on the mobo for the Lancool II's lighting, but it isn't necessary anyway on this build. Connect the two remaining fan cables, USB feedthrough, HD audio, and front I/O controls to the relevant headers on the motherboard. These are all clearly labeled, but if you have any difficulty, consult the motherboard manual.

Bundle your cables together using the Velcro straps and cable ties, but don't worry if cable management isn't your forte: Remember those two large shrouds we removed? Return those to the case once your cables are all plugged in, concealing all your cables. With that done, return the side panels and close this case up—build complete! But we're not quite done yet...

9 BIOS BOTHER

AS IS OFTEN THE CASE with modern RAM kits, you're going to need to take a trip into the BIOS to get the most out of your memory. Fortunately, the Asus Prime B460M-A has a nice, streamlined UEFI BIOS. All you need to do to improve memory performance is slap the XMP to "enabled" in the EZ Mode version of the BIOS, and you'll reap the benefits of the full speed supported by the motherboard and processor. You can also tweak the system fan curves. Since we've got a powerful air cooler, and the Core i3-10100 runs relatively cool anyway, adjusting the fan curves for lower speeds when idling or during non-intensive tasks will allow for a quieter running system. If you add additional drives later on, come back to the BIOS and adjust the boot priority so you're still booting from the 860 Evo.



Q-Fan Control

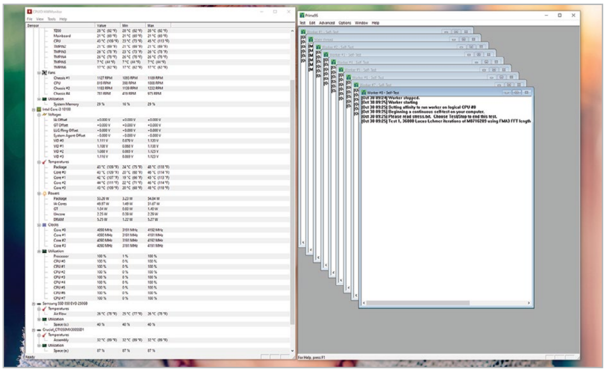
Select your target fan and then move the slider to select any of these profiles:(Standard, Silent, Turbo and Full Speed). You can also move the slider to Manual and manually configure the fan's operating speed.

© ASUS

10 SOFTWARE SORTED

YOU'LL NEED to install Windows here, but that process is fully guided in-OS. Instead we'll provide some software recommendations to help everything run smoothly. CPUID offers two handy programs, CPU-Z and HWMonitor. The former lets you check that your components are functioning properly, while the latter is a simple system-monitoring tool.

To stress-test your machine, download Prime95 for free. Use this in conjunction with HWMonitor to perform a blended function "torture test" on the CPU, which will push the chip to its thermal limits. HWMonitor keeps track of max temps, so leave Prime95 running for a few minutes then check it. Your CPU temps shouldn't rise higher than 50C with this cooler; if the chip gets too hot, check your fans are connected and functioning.



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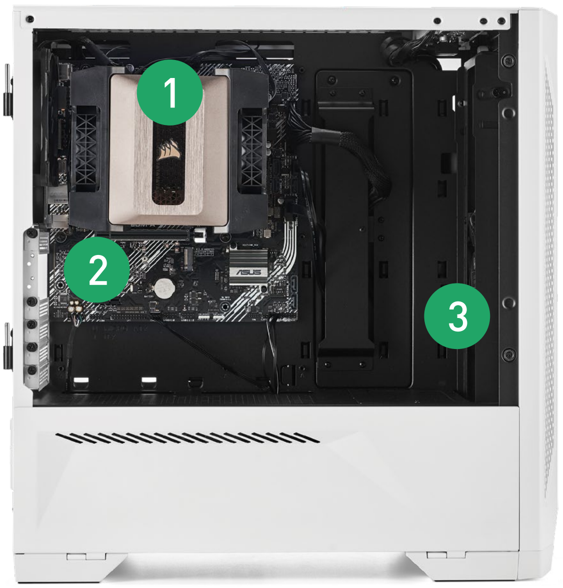


1 The Corsair A500 is a seriously bulky cooler, but it performs admirably even under duress, and is definitely quieter than an AIO cooler.

2 Adding a dedicated GPU to this machine would be a simple proposition, especially a cheaper model that doesn't require a dedicated power cable.

3 The metal "wings" and tempered-glass panels of the Lancool II are held in place by tiny but surprisingly powerful magnets.

FUNCTION OVER FORM

IT AIN'T EXCITING, but it works well. We're impressed with the overall performance of the Intel Core i3-10100, as it handled 4K display output with zero issues. As suspected, serious gaming isn't really an option here, but 2D indie titles should be able to run on this system if you're ever in the mood for a little bit of light puzzling or a visual novel experience. Those UHD 630 integrated graphics have been around for years, so we didn't really expect much.

CPU-bound performance was quite good. Our testing demonstrated a two-thirds performance increase on average against the Core i3-8100, with a slightly smaller generational leap between the 10100 and the 9100 it supersedes. Single-core performance hasn't improved that much between the generations, although the i3-10100 is the first Core i3 X100-spec budget Intel Core processor to utilize Hyper-Threading, which boosts performance in multi-threaded workloads.

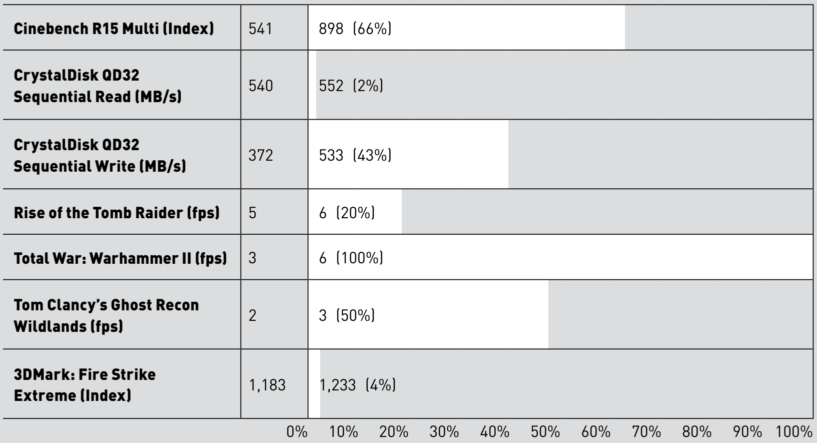
Our Samsung SSD might be almost three years old now, but it still pushes the limits of what the SATA III format is capable of. Upload and download speeds both sit close to the 550MB/s figure, which is generally the fastest transfer speed you're going to get from a 2.5-inch drive. While SATA III connections are capable of 600MB/s, you won't hit these speeds due to system overheads. A cheaper SSD might've been worthwhile, as the difference would've likely been negligible, but the Samsung drive is a reliable choice.

This machine outperformed our integrated graphics zero-point system. We do think that there's some money to be saved here, and Intel Graphics UHD 630 definitely isn't up to snuff when compared to its RX Vega competitors, but we can't complain. Dual-monitor support is an option (although twin 4K monitors might cause the iGPU to struggle), and we don't think we'd be able to squeeze much more performance from this rig without significantly increasing the price. A quad-core chip is sufficient for our needs here.

When it comes to overclocking, we're happy with our choice of components. Intel Turbo Boost is good, allowing for effortless "auto-overclocking" of the i3-10100's four cores, and while this processor technically isn't unlocked for overclocking, you can get a little extra juice by manually raising the BLCK frequency. Manual memory overclocking isn't necessary here, though, as you can improve memory performance by activating the XMP mode in the BIOS, which should boost the operating frequency beyond the 2,666MT/s default.

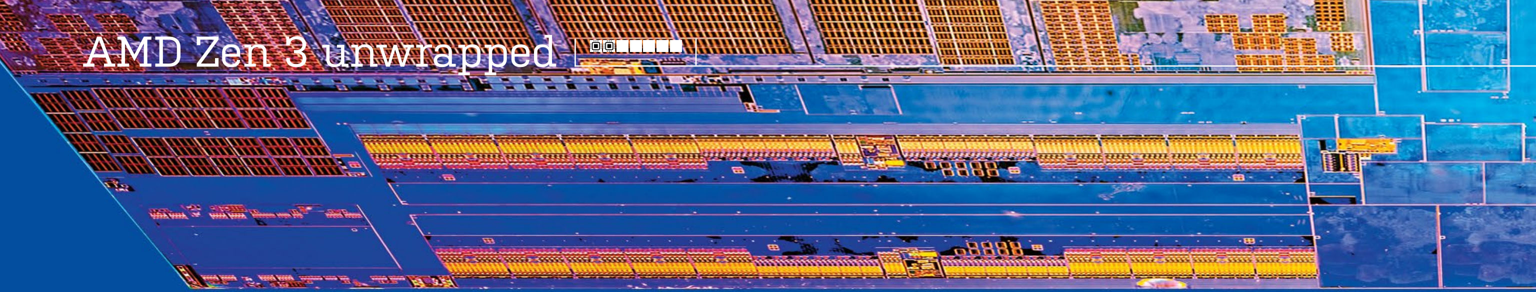
Is 500GB enough storage? Well, that depends. If you need a large amount of cheap, low-speed file storage, you can easily add a big HDD using the clip-in drive cages hidden under the PSU shroud. Otherwise, you might just want to spring for a 1TB SSD to replace the 860 Evo. ⏻

BENCHMARKS



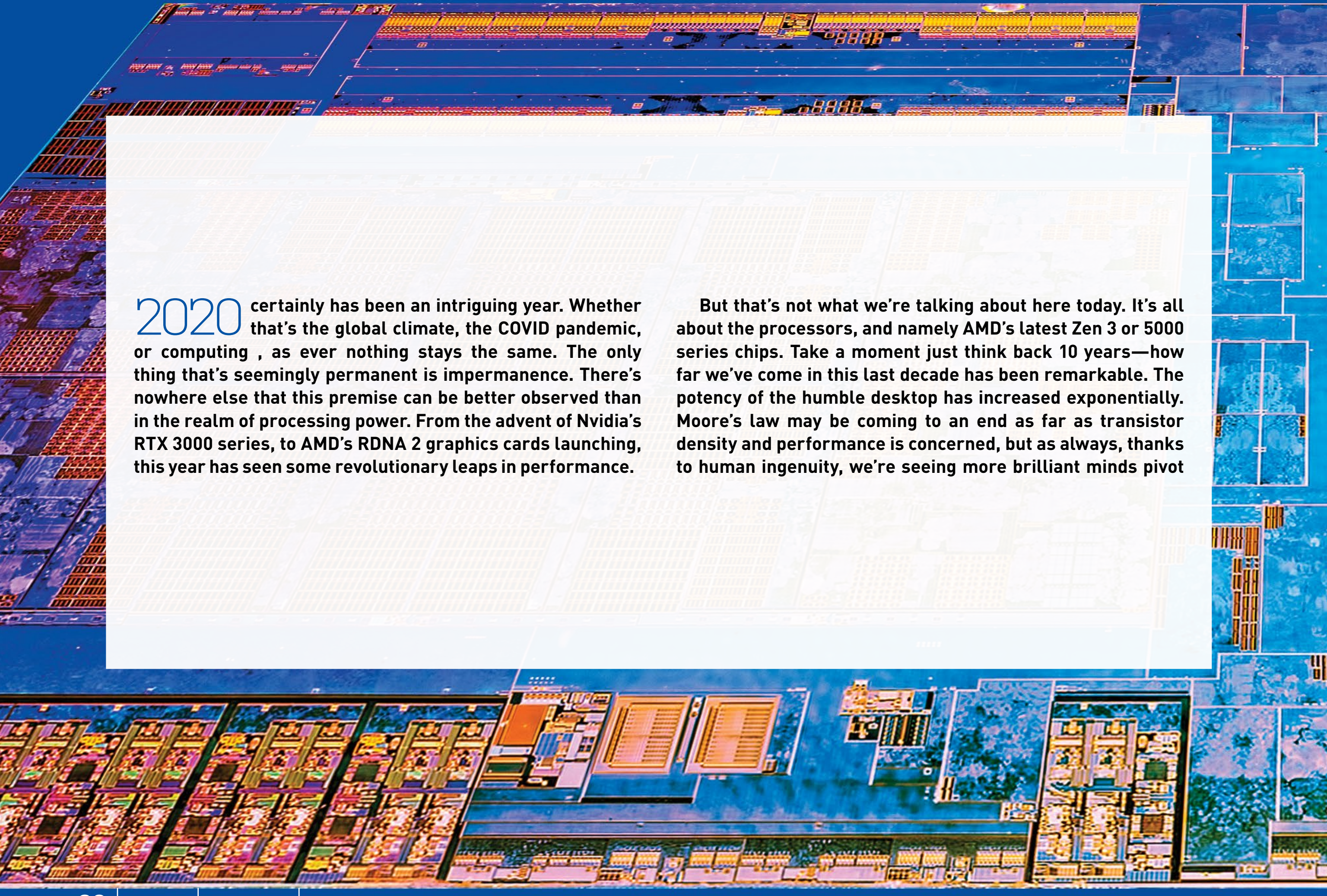
	ZERO-POINT	
Cinebench R15 Multi (Index)	541	898 (66%)
CrystalDisk QD32 Sequential Read (MB/s)	540	552 (2%)
CrystalDisk QD32 Sequential Write (MB/s)	372	533 (43%)
Rise of the Tomb Raider (fps)	5	6 (20%)
Total War: Warhammer II (fps)	3	6 (100%)
Tom Clancy's Ghost Recon Wildlands (fps)	2	3 (50%)
3DMark: Fire Strike Extreme (Index)	1,183	1,233 (4%)

Our zero-point consists of an Intel Core i3-8100, 8GB of Team Vulcan DDR4 @ 2400, and a 120GB Kingston SSDNow UV400. All tests were performed at 1080p at the highest graphical profile.



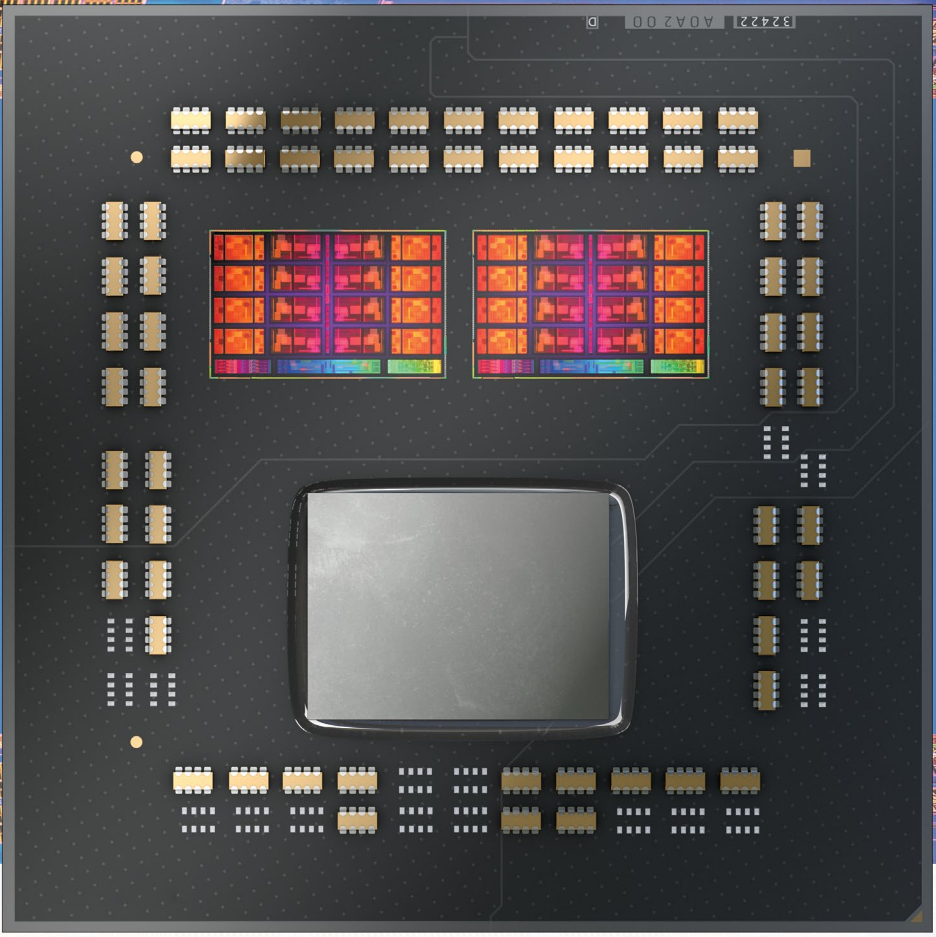
AMD ZEN 3 UNWRAPPED

The upcoming Ryzen 5000 CPUs significantly improve on an already successful 7nm design



2020 certainly has been an intriguing year. Whether that's the global climate, the COVID pandemic, or computing , as ever nothing stays the same. The only thing that's seemingly permanent is impermanence. There's nowhere else that this premise can be better observed than in the realm of processing power. From the advent of Nvidia's RTX 3000 series, to AMD's RDNA 2 graphics cards launching, this year has seen some revolutionary leaps in performance.

But that's not what we're talking about here today. It's all about the processors, and namely AMD's latest Zen 3 or 5000 series chips. Take a moment just think back 10 years—how far we've come in this last decade has been remarkable. The potency of the humble desktop has increased exponentially. Moore's law may be coming to an end as far as transistor density and performance is concerned, but as always, thanks to human ingenuity, we're seeing more brilliant minds pivot



themselves, to push processors further and harder than ever before. Long gone are the days of 10 percent performance increases year on year, that's for sure.

Since the launch of its first Zen architecture back in 2017, AMD has shown time and time again, with each generational advancement of its processors, that it's got more than enough clout to take on Intel on the grand stage of CPU dominance. And with this latest 3rd-generation architecture, it's aiming its sights squarely on Intel's IPC crown. Are we about to see a revolution in the way modern-day computational processing progress is led? How exactly has AMD managed to sneak in and steal the crown from the giant that is Intel? And is AMD's 7nm Zen 3 architecture that radically different to its previous iteration? What makes it all tick? Well if you're interested in that, dear reader, it's time to turn the page and find out what the future holds for all of us. –JARROD WALTON

© AMD

Architectural Advantages

AMD's CPU team is firing on all cylinders, making Intel's 14nm designs like Comet Lake look increasingly outdated. AMD's Ryzen 9 3950X was already making short work of Intel CPUs in just about every discipline—except gaming. Zen 3, also called Vermeer, aims to take on Intel in its last refuge, and the architectural changes required to do so aren't even that significant. Like Zen 2, Zen 3 uses TSMC's 7nm N7 process for the CPU chiplets, and 12nm FinFET for the IO chiplet. However, a few smart adjustments are set to make a big difference.

Putting things into perspective, Intel now has SuperFin, the marketing name for its third generation 10nm lithography that's already used in the new Tiger Lake CPUs. But Tiger Lake is mobile-only and currently tops out at four-core/eight-thread designs, and it will be a while before up to eight-core/16-thread chips launch. Intel also has Rocket Lake coming in Q1 of 2021, which will still use 14nm lithography, but with a new architecture—the first truly new desktop architecture from Intel in over five years!

At a high level, AMD says the new Zen 3 CPUs boost IPC (Instructions Per Cycle) by 19 percent across a broad suite of test applications. That might not seem like much when new GPUs come out that improve performance by 30-50 percent, but IPC affects everything. What's more, AMD says that these IPC gains will be realized without having to change power targets relative to Zen 2, which means the top chips will still have a 105W TDP.

You can see the full rundown of AMD's upcoming Ryzen 5000-series CPUs in the table on page 35. AMD will initially launch with four models, replacing the most popular Zen 2 CPUs in its lineup. All of these new CPUs should drop into existing X570 and B550 motherboards after a BIOS update. At the top is the Ryzen 9 5950X, a 16-core/32-thread behemoth that can boost up to 4.9GHz—that's 200MHz higher than the 3950X. The base clock is technically 100MHz lower, but it's doubtful that it will matter, as the chips are almost certainly going to run in the 4.3-4.5GHz range even under full load. That same pattern of slightly higher clocks with the same core and thread counts continues down through the 12-core, eight-core, and six-core models.

Looking at the specs sheet doesn't tell the full story, however. The biggest change is the new unified L3 cache. Previously, AMD CPUs used two CCX blocks of four cores each, with an attached 8MB (Zen, Zen+) or 16MB (Zen 2) L3 cache per CCX. With Zen 3, the CCX becomes a native eight-core block with an attached 32MB L3 cache. To understand why this matters, we need to review some of the basics of how moderns CPUs work.

Understanding the Memory Hierarchy

All of our computing infrastructure, from tiny chips in smartphones up to massive supercomputer installations, works on a principle of tiered data. With modern applications potentially using gigabytes and even terabytes of data, the difficult problem is figuring out how to best organize access to all of that data. The solution that's used is known as the memory hierarchy, ranging from tiny amounts of capacity with effectively instantaneous access, up to massive storage clusters that can hold petabytes of data but may require seconds per access, and everything in between.

The fastest storage solutions are in the CPU registers, which are part of the ALUs (Arithmetic Logic Units) that do the actual calculations. There's no delay for a CPU working on data stored in a register, but the total number of registers is extremely limited. Without getting too deep into the technical details, there are only eight general-purpose registers exposed to software in modern x86 CPUs, with 16 MMX/SSE/FP registers and up to 32 AVX registers—the latter being used for various vector math functions. Each register is anywhere from 64 bits to as many as 512 bits in size. That works out to a maximum of 2KB of total register space for AVX-512 instructions, as an example.

Because register space is so limited, software ends up spending a lot of time storing existing values from registers and loading new values into registers. It's a constant juggling act, and often data will be kicked out of one register only to be needed a few dozen instructions later. That can be incredibly inefficient, and the solution is to add cache. CPUs typically have at least three levels of cache these days, each succeeding level being larger but slower than the lower-level cache.

Note that internal register renaming allows a CPU core to have more actual registers, but there are still normally only a few hundred total registers. Some architectures may even refer to the renamed registers as an L0 cache, but either way it's data that can be accessed with no delay penalty.

For example, L1 cache is often 64KB to 96KB in total capacity. Each line of the cache holds 64 bytes of data, the idea being locality of reference: If you access data stored at memory address 0x0100 as an example, the code is more likely to also access data

What your AMD Ryzen 5000 chip would look like without the IHS

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AMD Ryzen 9 3950X
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100-000000051
BF 1935PGS
9HH1665014466
DIFFUSED IN USA
DIFFUSED IN TAIWAN
MADE IN CHINA
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> AMD's Ryzen 3000-series processors were the first to house the Zen 2 architecture, despite the confusing name

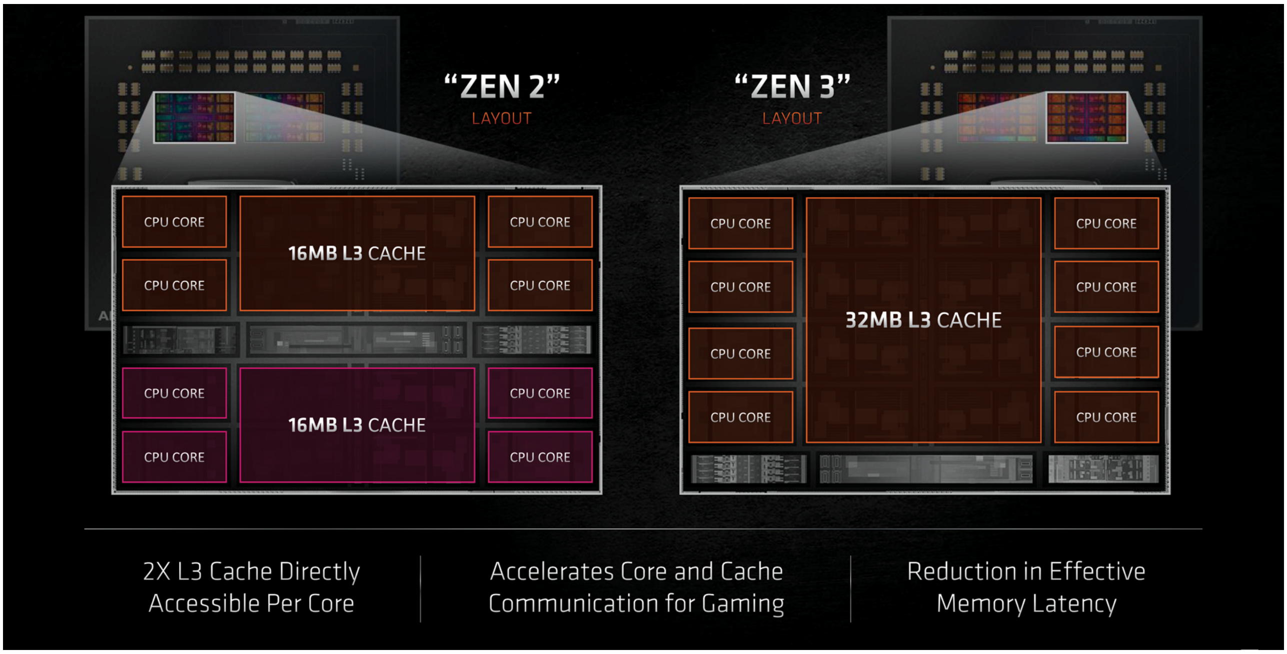
at 0x0108, 0x0120, and so on, in the near future. L1 cache sizes are larger than the registers, and access speed is usually around 1ns, give or take. That translates to anywhere from four to eight cycles, but because the CPU is aware of data accesses in advance, it's often able to pre-load data from the L1 cache into a register before it's needed. Basically, L1 cache is nearly instant access.

Because L1 cache is so fast, it also needs to be small, and most architectures split the L1 into a data cache and an instruction cache. Zen 2, for example, has a 32KB L1 data cache and a 32KB L1 instruction cache. Intel's Skylake and its derivatives also had a 32K+32K L1D and L1I cache size, while more recent architectures like Ice Lake and Tiger Lake have a 32K L1I cache and a 48K L1D cache size.

L2 cache is another big jump in capacity, and it's no longer split into separate data and instruction caches. AMD's Zen 2 and Zen 3 architectures stick with the same 512KB per core, while Intel's Skylake and derivatives have a 256KB L2 cache size—but the newer Ice Lake chips have 512KB L2 cache, and Tiger Lake is up to 1.25MB L2 cache per core. Intel's HEDT Skylake-X and derivatives had a 1MB per core L1 cache. Access latency on L2 cache is around 12 cycles, give or take, depending on the architecture. Some of the larger L2 caches may have slightly higher latencies as well, as there's a balancing act between size and latency (and set associativity, but that's another topic).

Finally, L3 cache ranges from about 2MB on the lowest tier modern CPUs (i.e. Intel Celeron) up to sizes as large as 64MB on consumer chips—the top Threadripper models even have as much as 256MB of L3 cache! Unlike the L2 and L1 caches, L3 cache is shared among all of the CPU cores. That means data accessed by core one and then subsequently needed by core eight could be in the L3 cache. With the large increase in capacity comes a similar increase in latency, and the Zen 2 architecture has about a 40-cycle latency for its L3 cache. Except when it doesn't, which we'll get to in just a second.

The whole idea of cache memory is to reduce access latencies on data that the CPU needs. A modern CPU running at 4GHz does four cycles every nanosecond. L1 cache may have an access time of less than 1ns, L2 is 3-4ns, and L3 is around 10-15ns (maybe more, depending on the architecture). But as bad as that sounds, it's nothing compared to system memory. Even though fast DDR4-3200 CL14 may have a theoretical latency of 8-10ns, real-use latency is more like 60-80ns, sometimes more. That means

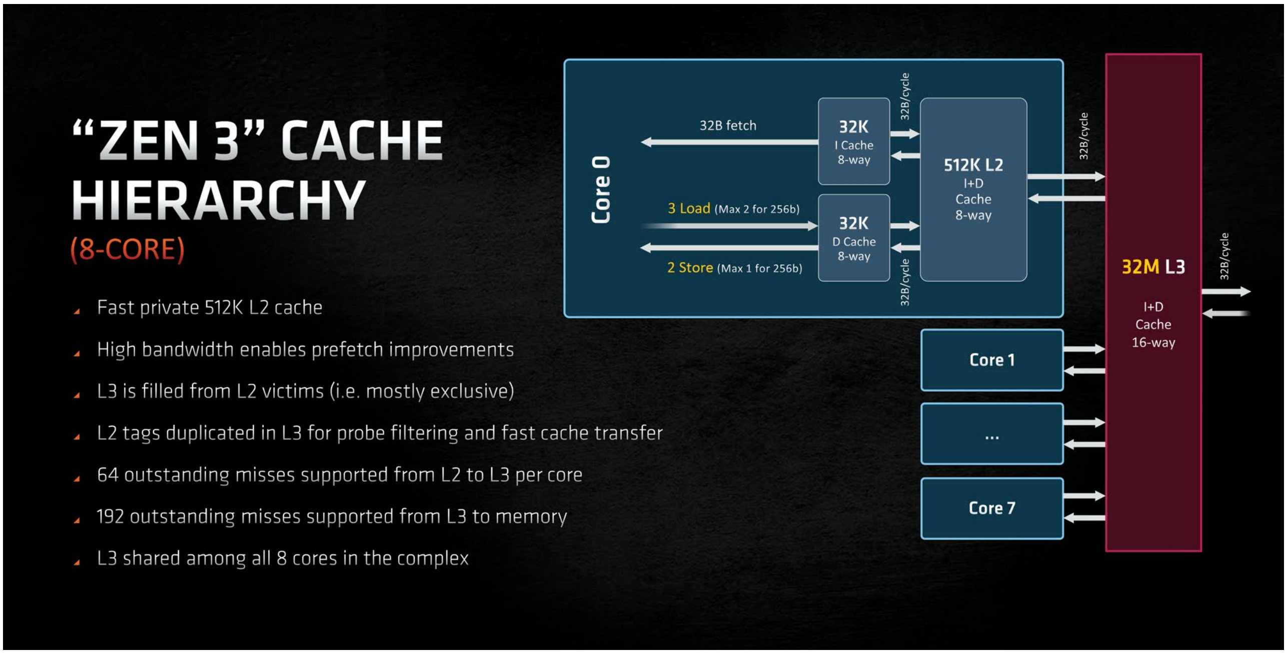


2X L3 Cache Directly Accessible Per Core

Accelerates Core and Cache Communication for Gaming

Reduction in Effective Memory Latency

Thanks to a core-complex redesign, Zen 3 can now connect 32MB of cache to eight cores, reducing access latency times significantly.



"ZEN 3" CACHE HIERARCHY
(8-CORE)

- Fast private 512K L2 cache
- High bandwidth enables prefetch improvements
- L3 is filled from L2 victims (i.e. mostly exclusive)
- L2 tags duplicated in L3 for probe filtering and fast cache transfer
- 64 outstanding misses supported from L2 to L3 per core
- 192 outstanding misses supported from L3 to memory
- L3 shared among all 8 cores in the complex

Core 0
32B fetch
32K I Cache 8-way
3 Load (Max 2 for 256b)
32K D Cache 8-way
2 Store (Max 1 for 256b)
32B/cycle
32B/cycle
512K L2 I+D Cache 8-way
32B/cycle
32M L3 I+D Cache 16-way
32B/cycle
Core 1
...
Core 7

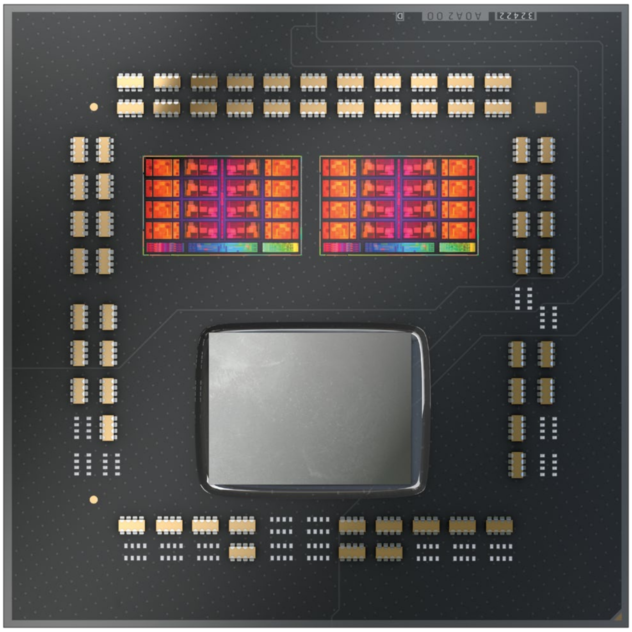
A reduction in latency like this will dramatically improve IPC performance, ideal for gaining that edge in gaming, and single core tasks.

the CPU can get stuck waiting for 250-400 cycles when pulling data from system RAM. And that's still nothing compared to SSD or HDD storage, which can cause thousands of cycles of delay.

In short, the cache hierarchy is critical to realizing the performance potential of modern CPUs. Improving the caches is thus one of the main ways of increasing CPU efficiency.

Reworking the L3 Cache for Zen 3

The biggest change with Zen 3 is that AMD has overhauled its L3 cache. Actually, it overhauled the whole CCX (Core Complex), which is the fundamental building block for AMD's Ryzen CPUs. Let's quickly talk about how Zen 2 and earlier Ryzen CPUs worked, and then we'll move on to how exactly Zen 3 improves things.



Each CPU chip or chiplet in the previous-generation Ryzen CPUs contained two four-core CCX blocks. The L3 cache was directly tied to the CCX, and while it was shared between all of the CPUs, access latencies weren't consistent. The cores in a CCX directly attached to the L3 for that CCX had a latency advantage. Cores in a different CCX had to route requests for data over the Infinity Fabric.

As an example, cores one to four on a Ryzen 9 3950X are in one CCX on the first chiplet, cores five to eight are in the second CCX on the same chiplet, cores nine to 12 are in CCX1 on the second chiplet, and finally cores 13-16 are in CCX2 on chiplet two. That's four groups of four CPU cores, and four 8MB L3 cache blocks.

Here's where things get difficult. Every L2 cache miss checks the four L3 caches to see if they contain the desired data. If the local L3 has a hit, though, things are much better than if the data is in one of the other L3 caches. That's because on Zen 2, the L3 cache access ends up going from the requesting core over the Infinity Fabric to the cIO chiplet, then to the CCX that has the data in its L3 cache, and then back over to the cIO chiplet before it ends up at the requesting CCX. Even on Ryzen 7 3700X, which only has

AMD has had to redevelop the L3 cache for Zen 3 chips quite radically

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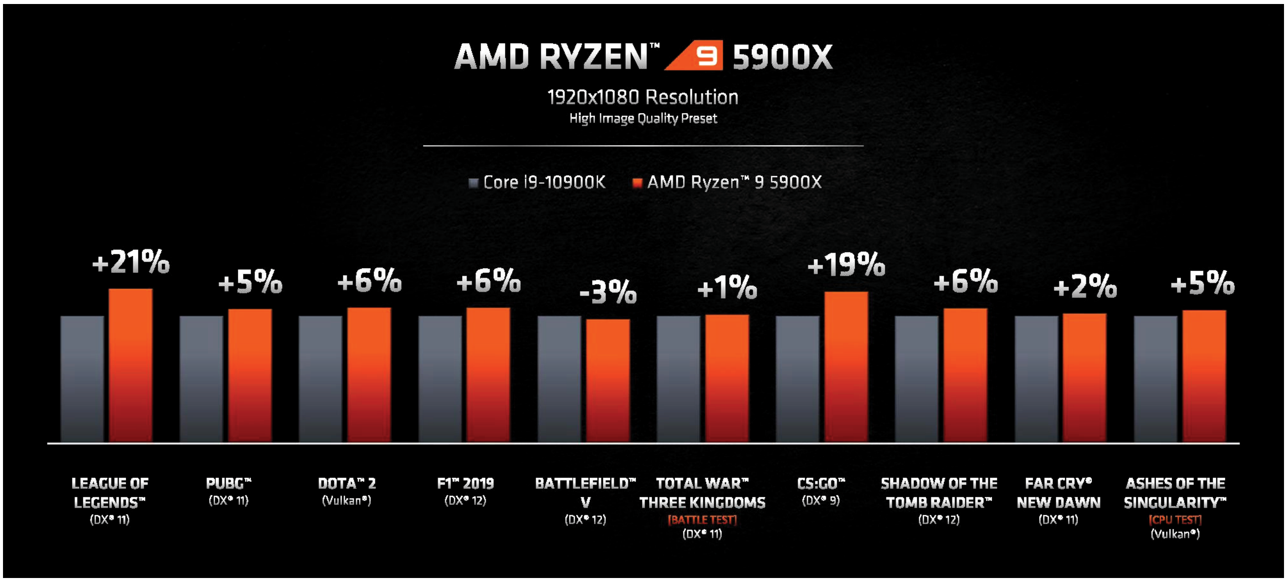

Comparing AMD's Ryzen 9 5900X 12 core to Intel's Core i9-10900K sees significant improvement in almost every single title at 1080p.

a single CPU chiplet and the cIO chiplet, L3 cache requests from CCX1 to CCX2 are routed that way.

It's messy and slow, and the solution is to move away from a four-core CCX with attached 16MB L3, to an eight-core CCX with an attached 32MB L3. That's basically the biggest change with Zen 3 compared to Zen 2. We don't have hard data on how memory latencies improve yet, but even though the larger L3 may be slightly slower, overall cache latencies should be much lower.

There are two reasons for this. First, in single-compute chiplet Zen processors (e.g. the eight-core 5800X and six-core 5600X), there won't be any L3-to-cIO chiplet traffic to worry about. Second, even on the dual-compute chiplet processors, there won't be any Infinity Fabric traffic for L3 requests from the same compute chiplet; it's only L3 accesses from one compute chiplet to the other that route over the Infinity Fabric. That's a net reduction in traffic, and a reduction in latency.

Other Changes and Non-Changes for Ryzen 5000

Interestingly, there are a lot of things that AMD isn't changing for the Zen 3 and Ryzen 5000 launch. For starters, there won't be a new chipset. Existing X570 and B550 boards should have updated firmware in place to support the new CPUs, though some new board designs will inevitably arrive specifically built for Zen 3. AMD previously said it wouldn't support Ryzen-5000 CPUs on earlier AM4 chipsets and motherboards, but community feedback prompted a change of heart. X470 and B450 boards will now get updated firmware for Zen 3, with some limitations. The boards still won't support PCIe Gen4, but there are other caveats.

First, the new firmware will drop support for older AMD CPUs. Right now, an X470 board can run Zen, Zen+, and Zen 2 CPUs and APUs. After flashing the BIOS, the board will only support Zen 3. Second, the flash will be one direction only for some reason, and AMD says it will require confirmation that a user has purchased a Zen 3 CPU before allowing the BIOS download. We're not quite sure how that's going to work, as it may be as simple as a message saying, "Please click to confirm you understand your board will no longer support Ryzen 3000 and earlier CPUs after flashing." Finally, the beta firmware updates for X470 and B450 won't begin arriving until January 2021.

Other things that remain the same include the cIO chiplet. It's still manufactured on GlobalFoundries' 12nm process. Considering the demand for TSMC's N7 node, this is a smart move. Nvidia likely couldn't come to an agreement with TSMC for enough N7 wafers to build its RTX 30-series GPUs there, opting instead for Samsung. The current cIO die has everything else that's needed, and apparently any power savings available by moving to 7nm were outweighed by the difficulty in procuring the wafers.

TDP, as noted, remains at 105W maximum, but that's not the real maximum. Short-term boost can go 35 percent higher than the TDP, so chips with a 105W TDP can actually run at up to 142W (and often will do so in enthusiast motherboards). The 65W chips, meanwhile, can run at up to 88W. There's a 142W maximum power limit on socket AM4 that remains in place (though obviously overclocking can exceed that).

AMD is also choosing to keep with its Ryzen 3000 XT series philosophy of not including a box cooler with anything above the Ryzen 5 line. That means the Ryzen 5 5600X will be the only CPU that comes with a cooler. The 5800X, 5900X, and 5950X will all require an aftermarket cooler, and AMD recommends liquid-cooling solutions.

Zen 3 Performance Preview

We'll have the full review of the Ryzen 5000-series parts next issue. Early benchmarks look promising, however, with a single-threaded result on the Ryzen 9 5900X of 631 for Cinebench R20, compared to 524 for the 3900X. That's right in line with AMD's 19 percent IPC claims, and perhaps more importantly, it's also a significant jump from the score of 544 on the Core i9-10900K. Not only is AMD faster, but it does so while using significantly less power. (Disclaimer: That's an AMD benchmark result, and Cinebench R20 tends to favor AMD's architectures more than some other applications.)

Perhaps more important than 3D-rendering performance, AMD makes no apologies when it comes to gaming capabilities. In our own testing, the Core i9-10900K was around 10 percent faster across a gaming test suite at 1080p ultra using an RTX 2080 Ti. Across a test suite of 10 games, AMD shows the 5900X matching or beating the 10900K—not by a lot, but it's better than trailing.

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AMD ZEN 3 RYZEN 5000-SERIES CPUS

	Ryzen 9 5950X	Ryzen 9 5900X	Ryzen 7 5800X	Ryzen 5 5600X
Cores/Threads	16 / 32	12 / 24	8 / 16	6 / 12
Base/Boost Frequency	3.4 GHz / 4.9 GHz	3.7 GHz / 4.8 GHz	3.8 GHz / 4.7 GHz	3.7 GHz / 4.6 GHz
TDP	105W	105W	105W	65W
L3 Cache	64MB (2x32)	64MB (2x32)	32MB (1x32)	32MB (1x32)
Price	$799	$549	$449	$299

We're certainly eager to put both the 5900X and 10900K to the test, and see how the chips perform with Nvidia's monster RTX 3090, or maybe even the RX 6900 XT.

Incidentally, AMD has a new feature it calls Smart Access Memory that will apparently improve gaming performance by around five percent when you pair a new Zen 3 CPU with a Big Navi GPU. It's yet another aspect of the new CPUs and GPUs we're looking forward to testing.

That brings up a few final interesting items of note. Intel still doesn't have a desktop PCIe Gen4 platform, and it won't until Rocket Lake arrives—which will probably be in March 2021. Intel is promising up to 18 percent IPC gains for single-threaded workloads with Rocket Lake, along with PCIe Gen4 capability. The problem is that Rocket Lake will apparently top out at an eight-core/16-thread configuration. AMD currently enjoys a PCIe advantage, a process technology advantage, and a core-count advantage. And Intel's first SuperFin desktop chips may not arrive until late 2021.

This is potentially the biggest lead AMD has had relative to Intel since the early days of Athlon 64, more than 15 years ago. Perhaps it's no surprise that AMD is also planning to increase prices by around $50 across its suite of Ryzen 5000 CPUs. Intel, meanwhile, appears to be countering with price cuts, but even that may not be enough to stay competitive in the coming year.

OTHER ZEN 3 ARCHITECTURAL UPDATES

Besides the reworked L3 and CCX, Zen 3 will offer numerous smaller changes. Overall, AMD claims a 19 percent improvement in IPC. Probably a big chunk of that comes from the L3 cache, but it still means a 4GHz Zen 3 chip as an example should perform as well as a 4.75GHz Zen 2 chip—or that a 4.4GHz Zen 3 CPU would be the equivalent of a 5.25GHz Zen 2 chip, which of course never existed.

AMD says the Zen 3 CPUs also have 24 percent better power efficiency compared to Zen 2 running at the same clocks. Improvements to TSMC manufacturing help to boost clock speeds a bit, so TDP isn't lower. The L3 cache design also contributes to the lower power use, since a reduction in signaling traffic over the Infinity Fabric will cut power use. Combined with TSMC's improvements in its manufacturing, the net result should be higher clock speeds.

That's about it as far as architectural changes go. AMD hasn't revealed all of the details, but it sounds as though the biggest change will be the move to a unified L3 cache and eight-core CCX. Even the compute chiplets haven't significantly changed in size. The Zen 2 compute chiplets were about 74mm square, and the new Zen 3 compute chiplets are at most 80mm square. That's not too surprising, as the dual-compute chiplet plus cIO chiplet form factor precludes using anything significantly larger for the die size.

CROSSHAIR VIII
START
RESET

Your X570 motherboard will be fine if you want to upgrade to Zen 3.

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BUILD A JELLYFIN MEDIA SERVER

Set up your own powerful—and completely free—alternative to Plex and Emby with *Nick Peers*

ANYONE WHO LOVES to stream media from their own personal library will have heard of Plex or Emby. Both offer an amazing user experience and powerful features, but they also come with one major pitfall: The need to pay a subscription to access their best features, such as live TV and DVR support, as well as hardware-accelerated transcoding. Those subscription costs can soon mount, but the good news is that there's a completely free and open-source pretender to their crown coming up fast in the rear-view mirror.

The usurper in question is Jellyfin. Although it only came into existence a mere two years ago—forked from the last open-source release of Emby—it's developed swiftly into a genuine rival to its established peers, boasting all their best features, including those hidden behind the Plex Pass or Emby Premiere paywall. That's in no small measure because it's promised to avoid commercialization, which has in turn attracted a flurry of donations and developers to the project.

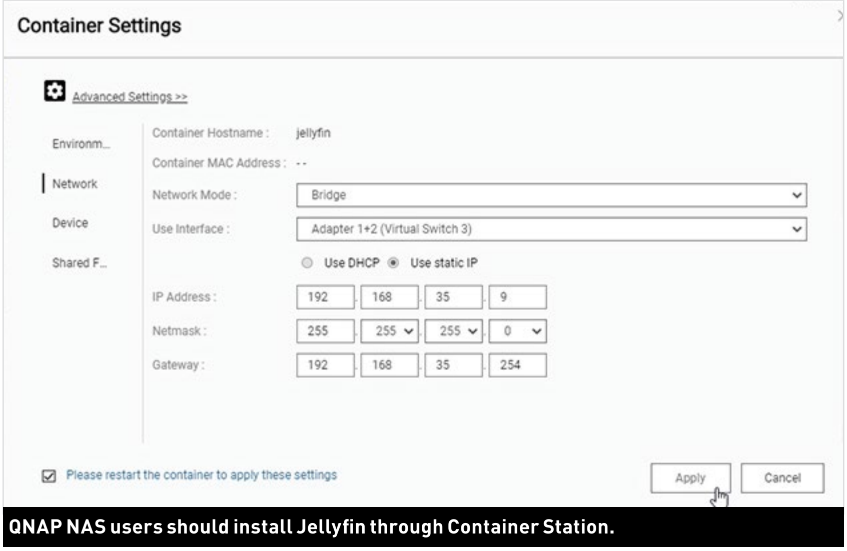
Read on to discover what makes Jellyfin a viable alternative to its better-known peers, and learn all you need to know about setting up and running your own Jellyfin server for the benefit of you, and your household.

GETTING STARTED

As we've stated, the obvious reason why you'd want to tear up your Plex or Emby installation and start again with Jellyfin is cost—the latter's promise to remain free and open source forever instead of chasing the dollar sign means that the features you can enjoy now will never be hidden behind a paywall. That's all well and good, but surely all this free goodness comes with a catch, right?

Not really: Sure, Jellyfin isn't quite as polished as its rivals, but all the core functionality is there, and thanks to its origins, you don't have to reinvent the wheel to switch from Plex or Emby. You won't need to rename or reorganize any of your existing media collection at all to get the most out of the software—just point Jellyfin to your existing media folders and it'll do the rest.

Jellyfin's user interface will—unsurprisingly—be instantly familiar to Emby users, and it doesn't take much work for Plex users to switch either, although you'll find that Jellyfin's UI isn't quite as intuitive (on the upside, it offers a lot more control). The blue and purple color scheme is fully customizable too, and everything is very pleasing on the eye, with plenty of familiar elements to help you acclimatize to your new environment. One area where Emby and Plex still hold an advantage is with client support, but as the boxout opposite reveals, Jellyfin is closing the gap fast.


Container Settings

Advanced Settings >>

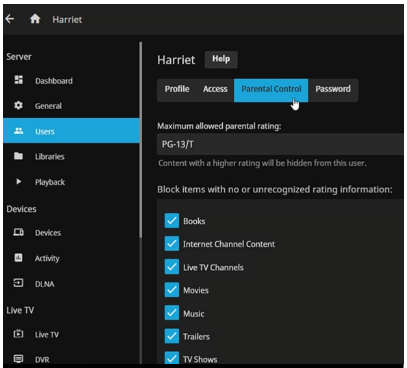
Container Hostname : jellyfin
Container MAC Address : --
Network Mode : Bridge
Use Interface : Adapter 1+2 (Virtual Switch 3)
○ Use DHCP ● Use static IP
IP Address : 192 168 35 9
Netmask : 255 255 255 0
Gateway : 192 168 35 254

☑ Please restart the container to apply these settings

QNAP NAS users should install Jellyfin through Container Station.

LOCAL AUTHENTICATION

One major plus in favor of Jellyfin is that it doesn't use any cloud-based authentication for users. A Plex.tv account is mandatory for both local and remote connections in Plex, while Emby Connect is required should you wish to open up access to your Emby server over the internet. Jellyfin ditches both in favor of continuing Emby's original approach: Direct connections to your server, with user profiles set up and managed locally, and no centralized harvesting of your data (or the privacy implications that come with it). On the downside, setting up remote connections requires a more work, but follow our advice in the "Remote Access" box and set up a secure connection for trusted devices through a reverse proxy.

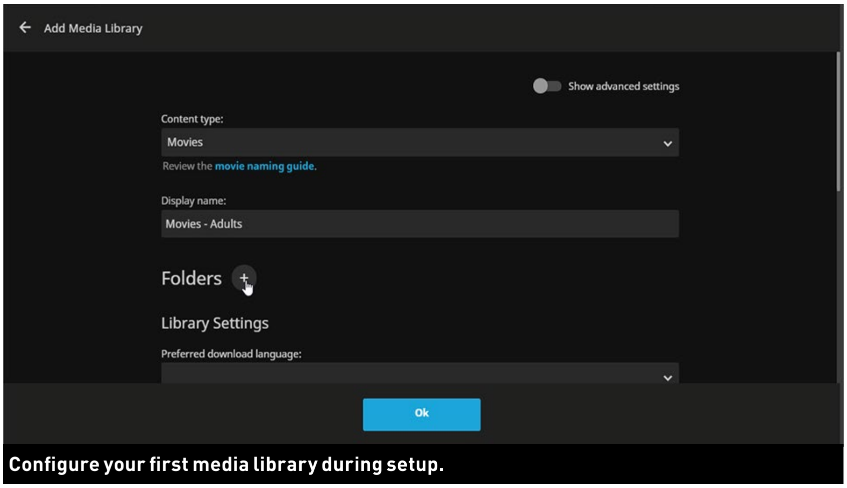


Harriet Help

Maximum allowed parental rating:
PG-13/T
Content with a higher rating will be hidden from this user.

Block items with no or unrecognized rating information:
☑ Books
☑ Internet Channel Content
☑ Live TV Channels
☑ Movies
☑ Music
☑ Trailers
☑ TV Shows

The Dashboard is where you configure all aspects of Jellyfin, including its users.



Content type:
Movies
Review the movie naming guide.

Display name:
Movies - Adults

Folders

Library Settings

Preferred download language:

Configure your first media library during setup.

And what about features hidden behind Plex's and Emby's respective paywalls? Jellyfin provides support for live TV and DVR—not as advanced as its rivals, but still usable, although you'll have to subscribe ($25/year) to the Schedules Direct EPG service. It also supports hardware-accelerated transcoding using your server's graphics card to reduce the burden on the CPU.

HARDWARE CONSIDERATIONS

The Jellyfin server can be installed on Windows, Mac, and a range of Linux distros, and it can also be installed using Docker (although hardware acceleration is harder to apply in a Docker container). In terms of raw hardware, Jellyfin can be run on quite modest setups, particularly if you can minimize "transcoding."

Transcoding occurs when your client device doesn't support the file format of your media. It's normally pretty CPU-intensive, which is why hardware acceleration can make all the difference, transferring some of the burden onto your graphics chip or card. Jellyfin's support extends across all major platforms, including Intel (QSV), Nvidia (NVENC), and AMD (AMF).

Of course, the best approach is to avoid transcoding entirely. By ripping your media in a universal format (MP4 container, H.264 video codec, AAC audio codec), you should find that most of your clients can stream the files without requiring any transcoding, thus reducing the demands on your server. Minimize transcoding, and you'll find that Jellyfin runs happily on a mid-range SOHO NAS,

© JELLYFIN

such as our QNAP TS-251+ NAS with 2013 quad-core Celeron CPU and 8GB RAM, or even a Raspberry Pi 3 or later.

One final consideration is the speed of your internet connection. If you plan to open your server to remote access over the internet, for your own on-the-road use or to share media with your household, then you need to benchmark your upload speeds using the likes of Speedtest (www.speedtest.net). Compare these results with the typical bitrates required to stream content to determine how many remote streams your connection can handle simultaneously.

INSTALL JELLYFIN

Time to install Jellyfin onto your server. Head to https://jellyfin.org/downloads where you'll find links to downloads for Windows (both portable and installer) and Mac, plus terminal commands for various flavors of Linux and Docker. While Jellyfin provides its own official Docker image, we made use of Linuxserver's Jellyfin container (https://hub.docker.com/r/linuxserver/jellyfin) for our QNAP thanks to its easy configuration. We also chose a bridged network rather than the NAT settings, for two reasons: One, it simplifies setting up secure remote access; and two, it ensures that live TV can work without problems.

Whatever your method of choice, installation is simple, and once complete you're ready to log on to the server through a web browser. Head to http://192.168.x.y:8096 (substitute 192.168.x.y for your Jellyfin server's internal IP address, or http://127.0.0.1:8096 if you're accessing it from the same computer it's installed on).

The first-run wizard will appear—Emby users will recognize it instantly—which is easy to work through. Start with your preferred display language (English United States is the default). Click Next.

Your next job is to set up the master user account for Jellyfin. This will be your account, and you'll have full access to all aspects of Jellyfin, including server management. Give yourself a suitable username ("Bob" for example) and don't skip the option to password-protect it, particularly if you plan to share your Jellyfin server over the internet.

CONFIGURE YOUR FIRST MEDIA LIBRARY

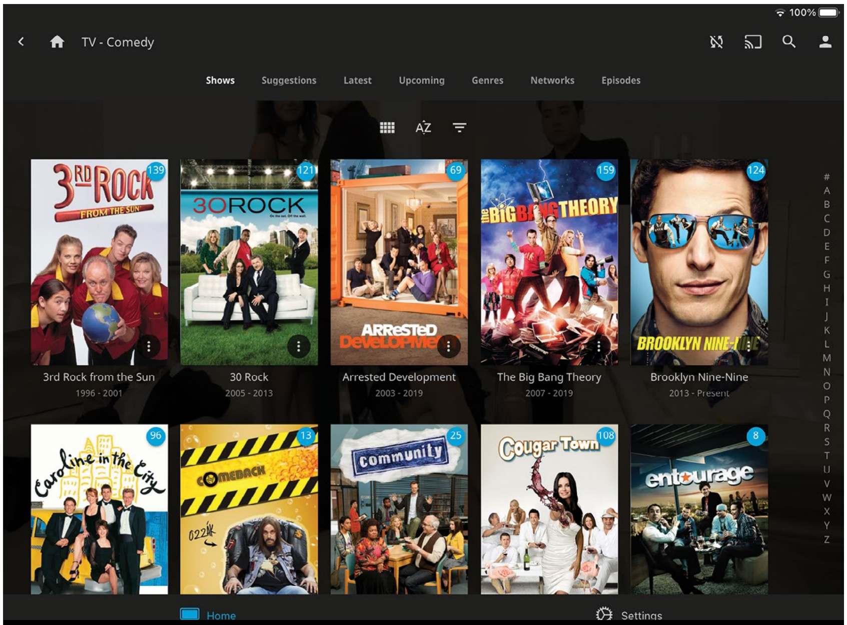
You will now be prompted to set up your first media library. Click "Add Media Library" to get started. Start by choosing your content type: Movies, Music, TV Shows, Books, Photos, Music Videos, and a catch-all Mixed Content are all available. Your library will be named for the content type you pick, but you can edit this as you see fit.

Next, click "+" to select the folder (or folders) containing your library's content. Once done, scroll down to access library-specific settings. Set a preferred download language and country that will be used to display the information about the content in your library.

Beneath this are the "scrapers" Jellyfin will use to populate your library with metadata and artwork. Untick any you wish to ignore, or click and drag to rearrange the order of preference in which they're used. Finally, you'll see some settings related to how the downloaded data is stored—ticking "Nfo" and "Save artwork into media folders" will allow other media servers, including Emby and Kodi, to share metadata, but introduces clutter into those folders and requires write-access to your media folders, which isn't a given in Linux-based iterations of Jellyfin.

Flick the "Show advanced settings" switch at the top to reveal even more options, such as options to pull in artwork and whether you want to "download images in advance," which basically means downloading them when media is imported into your library instead of when requested by a Jellyfin app.

Once you've configured your library, click "OK," then repeat for any other

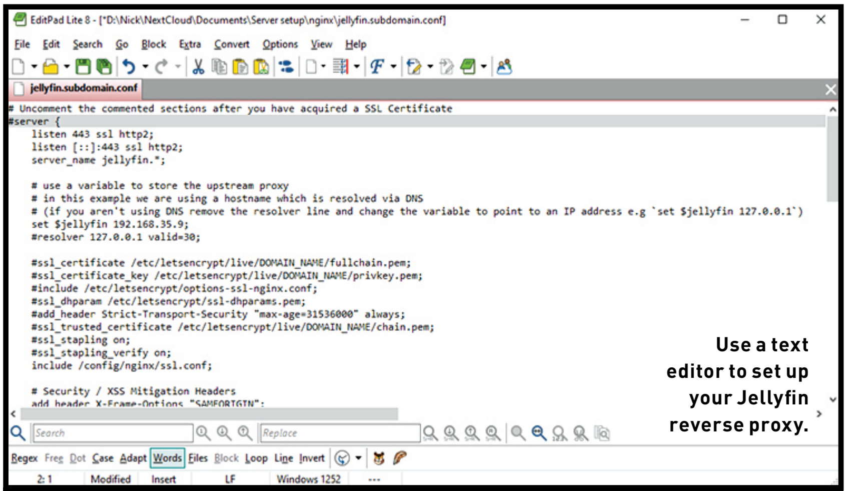


ACCESS JELLYFIN CONTENT

Any media server will live or die on how easy it is to access your content from a variety of platforms and devices. Over the past year, Jellyfin has worked hard to cut the gap between it and its longer established rivals, so that most major platforms are now supported—for free.

To see what platforms currently support Jellyfin, visit https://jellyfin.org/clients/—you'll find a range of releases (although beware, the Jellyfin for Desktop client currently has no official releases; try Jellyfin MPV Shim instead). Both Android and iOS are covered, along with a growing range of smart TV platforms: Boxes like Roku, Amazon Fire TV, and Android TV have native apps, while Apple TV owners can access Jellyfin content through the Infuse app. Also supported are Chromecast and AirPlay. Dedicated apps for Xbox One, Samsung (Tizen), and LG (webOS) TVs remain in development.

Once a client is installed and launched for the first time, you'll be prompted to enter your Jellyfin server address. If you're primarily connecting through your home network, use the local IP address (http://192.168.x.y:8096 by default) to enjoy a faster connection and fewer streaming restrictions. Many apps let you store multiple server setups, so simply add your server's remote address (https://jellyfin.domain.com for example) alongside it to provide access on the road when you need it.


EditPad Lite 8 - [*D:\Nick\NextCloud\Documents\Server setup\nginx\jellyfin.subdomain.conf]
File Edit Search Go Block Extra Convert Options View Help
jellyfin.subdomain.conf
Search
Replace
Regex Free Dot Case Adapt Words Files Block Loop Line Invert
2: 1 Modified Insert LF Windows 1252

```
# Uncomment the commented sections after you have acquired a SSL Certificate
#server {
    listen 443 ssl http2;
    listen [::]:443 ssl http2;
    server_name jellyfin.*;

    # use a variable to store the upstream proxy
    # in this example we are using a hostname which is resolved via DNS
    # (if you aren't using DNS remove the resolver line and change the variable to point to an IP address e.g `set $jellyfin 127.0.0.1`)
    set $jellyfin 192.168.35.9;
    #resolver 127.0.0.1 valid=30;

    #ssl_certificate /etc/letsencrypt/live/DOMAIN_NAME/fullchain.pem;
    #ssl_certificate_key /etc/letsencrypt/live/DOMAIN_NAME/privkey.pem;
    #include /etc/letsencrypt/options-ssl-nginx.conf;
    #ssl_dhparam /etc/letsencrypt/ssl-dhparams.pem;
    #add_header Strict-Transport-Security "max-age=31536000" always;
    #ssl_trusted_certificate /etc/letsencrypt/live/DOMAIN_NAME/chain.pem;
    #ssl_stapling on;
    #ssl_stapling_verify on;
    include /config/nginx/ssl.conf;

    # Security / XSS Mitigation Headers
    add_header X-Frame-Options "SAMEORIGIN";
```

Use a text editor to set up your Jellyfin reverse proxy.

SET UP SECURE REMOTE ACCESS

Remote access allows you to stream from your Jellyfin server over the internet. Unlike Plex or Emby, which use their cloud-based authentication systems to simplify the connection, you'll need to set this up manually. It's a good idea for security purposes to ensure all remote connections are secure (HTTPS rather than HTTP), and the easiest way to do this is through an existing reverse proxy.

If you followed our tutorial in February 2020's issue to set up a Docker container with ngnix and LetsEncrypt, start by setting up a new subdomain (jellyfin.domain.com) with a domain you own. Now delete and recreate the container, adding your subdomain to the "SUBDOMAINS =" environment setting.

Once the certificate has been generated, shut down the container. Now copy and paste the code underneath "Nginx" from a subdomain' at https://jellyfin.org/docs/general/networking/nginx.html into a blank text file, which you should save as jellyfin.subdomain.conf.

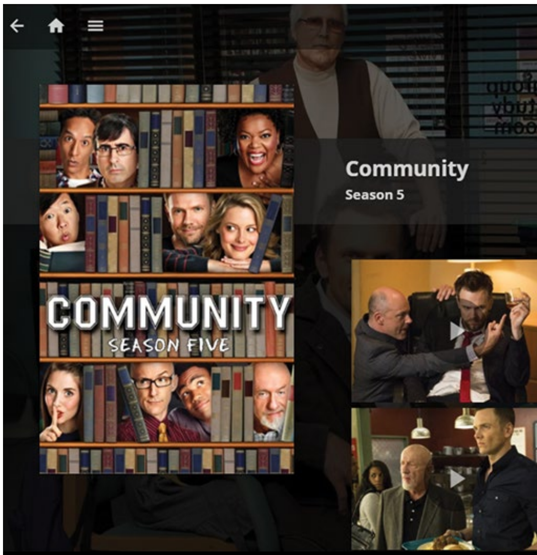
Remove the first server {} block listening on port 80—this is handled by your main configuration file (default under site-confs). Next, Uncomment out the two "listen 443" lines and change "DOMAIN_NAME" to "jellyfin.*" Change `set $jellyfin jellyfin;` to `set $jellyfin 192.168.x.y;`, substituting your server's local IP address in place of 192.168.x.y.

Add the following line beneath the ssl_stapling_verify_on; line:

```
include /config/nginx/ssl.conf;
```

Save the file, then upload it to the proxy-confs folder. Restart the container.

Now navigate to Jellyfin's server settings, then go to "Advanced → Networking." Tick "Enable HTTPS" and change the port number to 443. Click "Save." You should now have remote access enabled, and SyncPlay should work correctly too.



Jellyfin's easily navigable UI is packed with rich meta

© JELLYFIN

media libraries you'd like to configure now (you can add more later if you're impatient to get going). Click "Next" when done. Depending on the size of your media folders, setting up each library can take some time. You'll see content start to appear quickly, but it may take some hours before each library is fully populated.

Next, confirm your metadata language and country settings (English / United States) and click "Next." The next step confirms whether you want to open remote access to your server (for streaming content over the internet)—enabled by default—and whether you'd like to attempt UPNP port mapping. If UPNP is disabled on your router, you'll need to manually forward ports to your server's IP address. For more on remote streaming, check out the box above.

Once configured, click "Next," and you're done. Click "Finish," and Jellyfin will start scanning your media folders for content in the background. This can take some time depending on your server hardware, so now's a good time to leave Jellyfin to its own devices for a while.

FIRST-TIME LOGIN

You'll be shown to the main Jellyfin screen, which provides you with access to your media library with a variety of views: At the top are shortcuts to your individual media libraries, followed by the "Next Up" section, Jellyfin's equivalent of Plex's On Deck view for working your way through series. Beneath this you'll see the latest additions to each library.

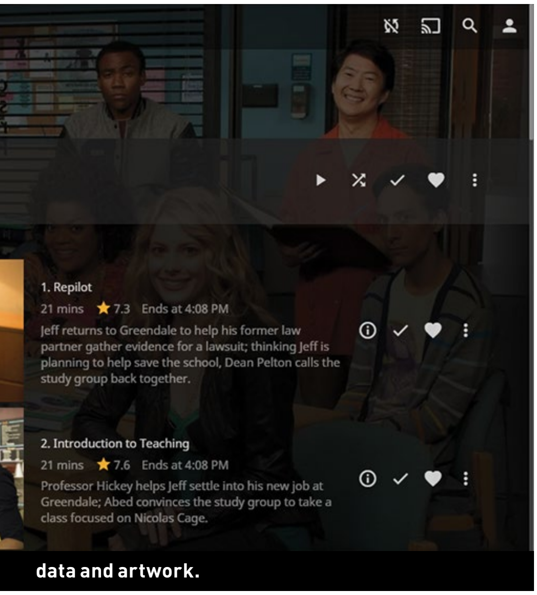
Browsing any of these views is self-explanatory, with plenty of on-screen navigation aids. At the top are a range of library views, from "Suggestions" to "Genres." Look out too for "Favorites," which lists any media you've marked by clicking the heart icon next to it, and "Collections," which enables you to manually group related items together (such as all the movies in a specific franchise, or a more eclectic choice such as movies featuring a specific actor).

Immediately below this are three buttons, enabling you to change your library view from the default poster-based view, with banners, lists, and thumbs all available. Next to this is the A-Z button, allowing you to sort your library by different criteria, while the final button allows you to apply various filters to the view, from features and genres to parental ratings and years.

When you select a specific movie, TV episode, or other piece of media, you'll be whisked to its own page, where you'll hopefully see a synopsis, as well as a summary of the media's audio and video type. If the media item contains a choice of video, audio, or subtitles, then look for dropdown menus enabling you to switch from the default choices before playing your movie.

FIX METADATA

As you browse your library, you're likely to come across the odd series or movie



1. Repilot
21 mins ★ 7.3 Ends at 4:08 PM
Jeff returns to Greendale to help his former law partner gather evidence for a lawsuit; thinking Jeff is planning to help save the school, Dean Pelton calls the study group back together.

2. Introduction to Teaching
21 mins ★ 7.6 Ends at 4:08 PM
Professor Hickey helps Jeff settle into his new job at Greendale; Abed convinces the study group to take a class focused on Nicolas Cage.

data and artwork.

that has been incorrectly identified. To fix this—and to make other metadata-related changes to your libraries—click the hamburger button in the top-left corner of the screen to slide out the main Jellyfin menu and choose "Metadata" under "Admin."

The Metadata Manager reveals an Explorer-like view of your media by folder. Drill down to a movie title, or parent folder for a TV show, and you'll see its metadata appear in the right-hand pane. You can manually edit this if you wish, but if you're attempting to fix an incorrect match, a quicker method is to click the vertical ellipsis button next to "Save" and then choose "Identify."

This will bring up a search tool. You can search by title and/or year (which should resolve most issues where an identically titled show or movie from a different year has been selected), but if this doesn't yield a result, go online to www.imdb.com or thetvdb.com to manually locate your show and grab its ID. Enter this into the relevant search field, and you're guaranteed to get the right match when you click "Search."

ADMIN DASHBOARD

Jellyfin's server can be further configured via its Dashboard, also accessible under the "Admin" section of the main menu. Configurable options are split into four sections: "Server," "Devices," "Live TV," and "Advanced," with Dashboard at the very top. It provides a handy overview of recent changes, which devices are currently connected, what's streaming and where.

Beneath this is "General," where you can change your server name and preferred language, followed by "Users."

NAME YOUR FILES

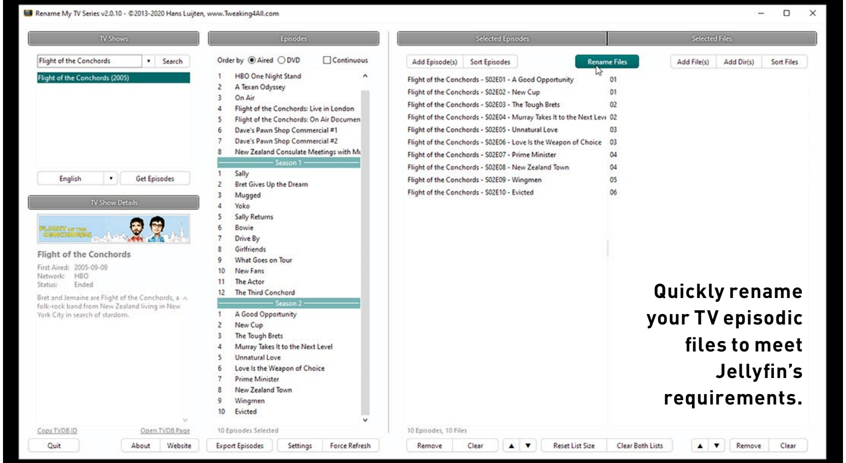
Your media server uses the filenames of your media to help identify and tag them correctly. Jellyfin follows the same naming conventions as Plex and Emby, so if you're migrating from these you should have little trouble with most of your content.

The only exceptions are likely to be TV series that share the same name as an earlier show, and any movie extras you have into the same folder as your original movie following Plex's naming conventions (see https://support.plex.tv/articles/local-files-for-trailers-and-extras/).

Regarding the latter, Jellyfin follows Emby's convention: Here, you simply create a subfolder called "Extras" inside the main movie folder, then move all your extras into there. You'll also need to rename the file—for example, "Avatar-deleted.mp4" should be renamed "Avatar Deleted Scenes.mp4" or even just "Deleted Scenes.mp4," as its filename is the title that Jellyfin displays underneath the main movie.

If you are only just starting out with your first media server, then here is our recommended basic naming convention nomenclature:

TYPE	FOLDER STRUCTURE	SYNTAX	EXAMPLE
Music	Music\Artist\Album	00.trackname.mp3	Music\a-ha\Cast In Steel\01.cast in steel.mp3
Movies	Movies\Title (year)	Title (year)	Movies\Ready Player One (2018)\Ready Player One (2018).mkv
TV shows	TV\Show Title\Season	TVshow – s01e01	TV\Community\Season 6\Community - s06e10.mkv



Rename My TV Series v2.0.10 - ©2013-2020 Hans Luijten, www.Tweaking4All.com

Flight of the Conchords (2005)

Flight of the Conchords
First Aired: 2005-09-09
Network: HBO
Status: Ended
Bret and Jemaine are Flight of the Conchords, a folk-rock band from New Zealand living in New York City in search of stardom.

Order by ● Aired ○ DVD ☐ Continuous

1 HBO One Night Stand
2 A Texan Odyssey
3 On Air
4 Flight of the Conchords: Live in London
5 Flight of the Conchords: On Air Documen
6 Dave's Pawn Shop Commercial #1
7 Dave's Pawn Shop Commercial #2
8 New Zealand Consulate Meetings with Mu
Season 1
1 Sally
2 Bret Gives Up the Dream
3 Mugged
4 Yoko
5 Sally Returns
6 Bowie
7 Drive By
8 Girlfriends
9 What Goes on Tour
10 New Fans
11 The Actor
12 The Third Conchord
Season 2
1 A Good Opportunity
2 New Cup
3 The Tough Brets
4 Murray Takes It to the Next Level
5 Unnatural Love
6 Love Is the Weapon of Choice
7 Prime Minister
8 New Zealand Town
9 Wingmen
10 Evicted

10 Episodes Selected

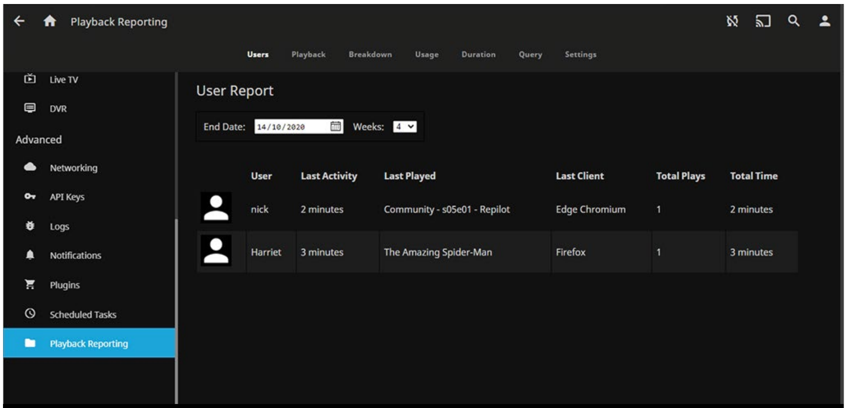
Flight of the Conchords - S02E01 - A Good Opportunity 01
Flight of the Conchords - S02E02 - New Cup 01
Flight of the Conchords - S02E03 - The Tough Brets 02
Flight of the Conchords - S02E04 - Murray Takes It to the Next Leve 02
Flight of the Conchords - S02E05 - Unnatural Love 03
Flight of the Conchords - S02E06 - Love Is the Weapon of Choice 03
Flight of the Conchords - S02E07 - Prime Minister 04
Flight of the Conchords - S02E08 - New Zealand Town 04
Flight of the Conchords - S02E09 - Wingmen 05
Flight of the Conchords - S02E10 - Evicted 06

10 Episodes, 10 Files

Quickly rename your TV episodic files to meet Jellyfin's requirements.

If you have multiple versions of the same movie—say a theatrical version and director's cut, or a 4K version for watching locally and an SD version for remote streaming —name each file like so: "Movie (year) – Version.mp4." "Version" can be anything you like—"1080p," "HD" or "Director's Cut"—and is displayed on screen to help you get the right one.

It's laborious to rename existing files by hand to meet these conventions, but various tools exist to make it easier: Filebot (www.filebot.net) covers music, movies, and TV shows, but costs $6 (one-year license) or $48 (lifetime license). If you're only interested in renaming TV shows, then Rename My TV Series 2 (www.tweaking4all.com/home-theatre/rename-my-tv-series-v2/) is completely free—and cross-platform. Change the filename format under "Settings" to "%N - S%SZE%EZ - %T" to match my recommendation above.



User Report

End Date: 14/10/2020 Weeks: 4

User	Last Activity	Last Played	Last Client	Total Plays	Total Time
nick	2 minutes	Community - s05e01 - Repilot	Edge Chromium	1	2 minutes
Harriet	3 minutes	The Amazing Spider-Man	Firefox	1	3 minutes

EXTEND JELLYFIN WITH PLUGINS

Like Emby, Jellyfin supports a wide range of plugins that provide access to all kinds of extra features and functions . Navigate to the Dashboard and click "Plugins" under "Advanced" to review them. You'll see that four metadata providers come pre-installed covering your music, movie, and TV libraries. Any with a vertical ellipsis button next to its name contain settings you can tweak by clicking the button and choosing "Settings." Switch to the "Catalog" tab to see what additional plugins are currently available through the official Jellyfin repo. You'll see they're split into six categories: "Authentication," "Channels," "General," "LiveTV," "Metadata," and "Notifications." Click one for a description and options to install it. You'll find plenty of potential interest: If you have a USB TV tuner then you'll find plugins supporting popular backends NextPVR, ServerWMC, and TVHeadend that you can configure to work with Jellyfin. An IPTV plugin provides support for IPTV, while Auto Organize lets you set up a folder that you can copy media into and let Jellyfin move across to the appropriate library folder. Open Subtitles lets you grab subtitles from the internet for those movies or TV shows without them already embedded, while Playback Reporting echoes Plex's dashboard where you can view server activity, including a list of what each user's been watching. The "Repository" tab is a recent addition and will in future make it easier for 3rd-party plugins to be developed and shared with the community.

If you're planning on sharing access to Jellyfin with other users—both locally and remotely—then you'll want to assign them own user accounts, which will give them their own custom access to Jellyfin, complete with their own personal deck for lining up TV episodes plus the ability to tweak certain aspects of their own personal experience. Click "+" to set up your first user: Assign them a name and password, and choose what libraries to give them access to. Click "Save."

Once a user is created, you'll gain access to four tabs of settings: "Profile," "Access," "Parental Control," and "Password." Under "Profile," you'll see options for enabling or disabling remote streaming, management of the server, and access to specific features, such as live TV, SyncPlay, and media downloading. "Access" is where you manage their access to both libraries and from specific devices, while "Parental Control" gives you handy control over children's access to content, with options for setting a minimum parental rating, plus limiting access by day and time. Use "Password" to assign a new password, or add a pin code. Click "Save" when you're done.

"Libraries" is—of course—where you go to manage existing libraries, as well as to add new ones (the process is identical to that in the first-run wizard). The final setting under "Server" is "Playback." Available options here include whether to use hardware acceleration for transcoding (if supported—remember, there may be a price to pay in terms of image quality, so experiment with both settings). You'll also find advanced conversion settings for transcoding to x264/x265—Handbrake users should recognize most of these options, and it's something that sets Jellyfin apart from Plex.

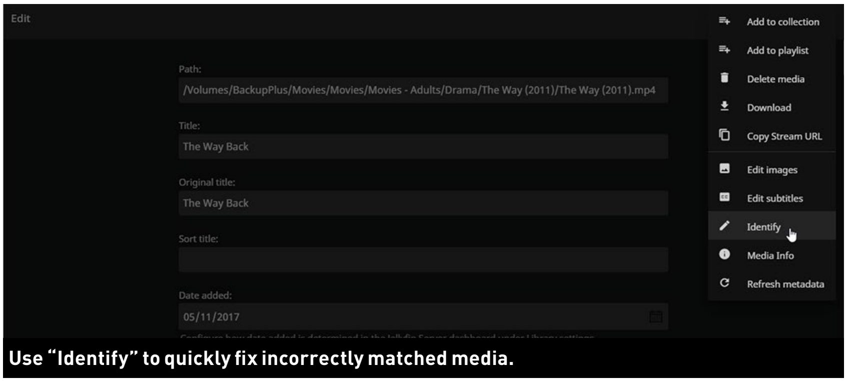
Remember how we mentioned earlier about how your internet upload speed will limit the number of streams you can serve? One way to ration your available bandwidth is to make use of the setting under "Playback → Streaming." Here you can set a per-stream bitrate limit; any media with higher bitrates will be transcoded to fit whatever limit you set, so bear this in mind if you're streaming from a low-powered device.

LIVE TV

If you've got a spare TV tuner knocking about, or an HD HomeRun device plugged into your network, then you can add both live TV and DVR facilities to your Jellyfin server, accessible through any client. You can even extend it to your family on a user-by-user basis via the "Profile" tab of their personal user settings.

Set it up via the main Dashboard—click "Live TV" on the left and click "+" to add your tuner. HD HomeRun tuners should be detected automatically, while IPTV channel playlists can be added via the M3U option. USB TV tuners require a compatible backend—NextPVR, ServerWMC, or Tvheadend—to be set up, and the appropriate plugin added to Jellyfin (see the plugins box).

Once added, you'll need to assign an EPG (electronic program guide) to allow you to browse and watch live TV, and set up scheduled recordings. Jellyfin supports just two types: Schedules Direct (which requires a $25/year subscription



Path: /Volumes/BackupPlus/Movies/Movies/Movies - Adults/Drama/The Way (2011)/The Way (2011).mp4

Title: The Way Back

Original title: The Way Back

Sort title:

Date added: 05/11/2017

Use "Identify" to quickly fix incorrectly matched media.

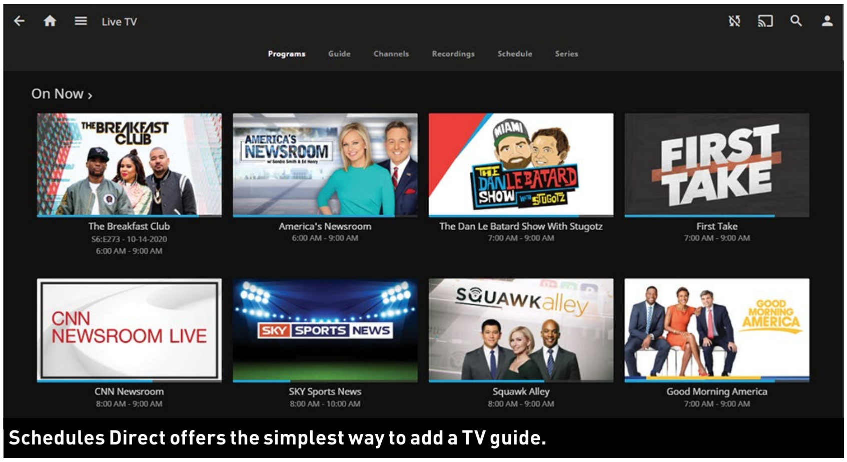
© JELLYFIN

after six-day free trial), and XMLTV. If you can track down a free XML feed, then the latter is the way to go, but it's a convoluted process involving converting online guides to XML files you can plug into Jellyfin, whereas Schedules Direct can be set up and linked within a matter of a few minutes.

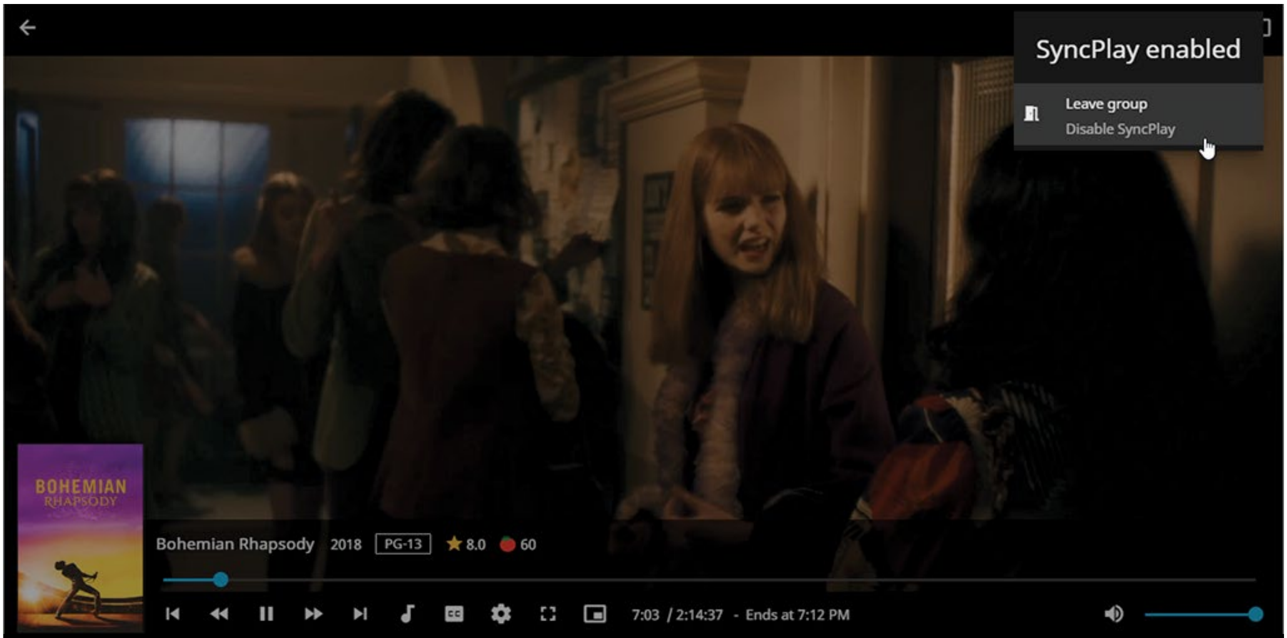
Once done, switch to the DVR section, and specify where to save any TV recordings you make. Note that these will be created as separate "Recorded TV" and "Recorded Movies" libraries in Jellyfin, so try to avoid selecting an existing library folder (or create a dedicated subfolder inside that folder—say \TV\Recorded\) to prevent the new libraries from displaying duplicate information. It's not as elegant as Plex's approach, whereby you can select a specific library to save a recording to, but it's better than nothing. Don't forget to scroll down and click "Save".

Once configured, Live TV will take a prominent spot on your home screen, with a shortcut to its own page, plus an "On Now" section providing convenient shortcuts to shows that are currently broadcasting. When you click on a show, you'll be offered the chance of recording it as well as watching it. When scheduling recordings, you'll see a series link option for a "set and forget" approach; this ensures that all future broadcasts are automatically recorded too.

By default, all streams are recorded uncompressed in MPEG2 format. You can manually convert these to MP4/H.264 recordings and then move them into your libraries, or you can make use of a script to perform the conversion. If you're running ffmpeg, Bill Thornton's post-process.sh script (https://gist.github.com/thornbill) will do—just invoke it from Jellyfin via the "Recording post processing" option under DVR settings.


Live TV
Programs
Guide
Channels
Recordings
Schedule
Series
On Now ›
The Breakfast Club
S6:E273 - 10-14-2020
6:00 AM - 9:00 AM
America's Newsroom
6:00 AM - 9:00 AM
The Dan Le Batard Show With Stugotz
7:00 AM - 9:00 AM
First Take
7:00 AM - 9:00 AM
CNN Newsroom
8:00 AM - 9:00 AM
SKY Sports News
8:00 AM - 10:00 AM
Squawk Alley
8:00 AM - 9:00 AM
Good Morning America
7:00 AM - 9:00 AM

Schedules Direct offers the simplest way to add a TV guide.


SyncPlay enabled
Leave group
Disable SyncPlay
BOHEMIAN RHAPSODY
Bohemian Rhapsody 2018 PG-13 8.0 60
7:03 / 2:14:37 - Ends at 7:12 PM

SYNCPLAY

One of lockdown's few pleasures is watching movies together with far-flung family via Zoom. Thanks to Jellyfin's new SyncPlay feature, it's easier than ever to watch the same movie without fiddling about trying to sync up everyone's playback.

The prerequisites are simple: Everyone needs access to your server plus the media library that's serving up the content. Once done, start playback on your main device and look for the "SyncPlay" button (next to "Cast"). Click this and choose "New group."

When your family launch their own instance of Jellyfin and click the "SyncPlay" button, they'll see your movie/episode title appear as a group that they can join. Clicking this should see them join your stream at the same point you're already at. Click play to continue watching. The sync may not be perfect—we had a brief but noticeable lag of about half a second—but unless you can hear each other's stream you should be able to live with it. Expect the feature to improve soon—planned features include the ability to manually tune out the delays.

TECH PORN

PERFORMANCE GEAR LAID BARE

Samsung Odyssey G7

LIGHT: It's one of the few inherent constants in our universe. Those photons that continually bounce around at a meagre 186,282 miles per second allow us to experience this fantastic place we inhabit, in a way that no other sense truly can allow for. As a species, without our keen eyesight, and those fateful particle waves enabling us to see, we would be bereft of a significant portion of our culture, art, and history. In fact, it's highly unlikely that we would've become as advanced and developed as we are today without it.

As we continue to delve deeper into the world of the technological, our demand and hunt for something that better imitates our vision in real life has intensified. Bringing our new simulated realities to life has meant pushing the limits of screen technology to the absolute edge in that perpetual pursuit.

We've come a long way, and as our technological foundries continue to advance, and the human brain thinks of ever-more inventive ways to replicate the very nature of our visual existence, we're starting to see some truly remarkable products make their way to the forefront of the enthusiast consumer ecosystem. The Samsung Odyssey G7 is one of those products.

Although not quite as gargantuan or as expensive as its 49-inch G9 brother, this flagship from Samsung features an impressive 240Hz refresh rate, 1ms G2G response time, QLED quantum-dot 1440p panel, with G-Sync and VA technology to produce rich, deep colors and superior clarity for all of your visual experiences. But even more pre-eminent than that, it does all of this while mimicking the contours found within the human eye itself, as it features a fantastically impressive, and a world-first, 1000R curve radius, making it one of the most immersive screens that we've ever seen. **–ZAK STOREY**

1 ULTIMATE VA TECHNOLOGY

The VA panel found at the heart of this technological marvel is incredible. Featuring a 1ms response time and a 240Hz refresh, it does all of this without compromising on color accuracy and refinement. Expect minimal to zero ghosting or blur.

2 1000R CURVE RADIUS

Designed to mimic the human eye, the Odyssey series packs an incredible 1000R radius. This makes it far more curved than any of the other monitors we've seen out there before—it's dramatic, even on the 27-inch model.

3 COLOR ACCURACY

Whether that's thanks to the HDR 600, or the QLED tech at its heart, the Odyssey G7 features impressive color accuracy straight out of the box. In fact it requires minimal to no calibration whatsoever, and with its 600 nits of brightness in HDR mode, makes it the perfect screen for any art worker who dabbles in gaming too.

SAMSUNG

THERE'S SO MUCH WE SHARE, IT'S TIME WE'RE

VIRTUAL MACHINES MADE MANIFEST

THESE DAYS it's one of the less-crazy conspiracy theories that the world isn't real and that all of *this*—peers around the decaying *Maximum PC* office—is an elaborate virtualized simulation run by some bored alien teen on their Apple IIq quantum computer. Brushing aside simpler questions such as, "Why?" and, "Could they bump up my pay check please?" it shouldn't mask that the modern world is in fact now largely run in a virtual world.

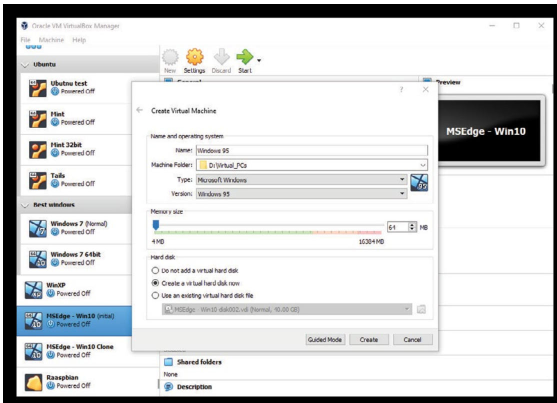
This text is being run as part of a Java Virtual Machine inside a browser. It's stored in the "cloud" as a managed virtual storage pool that'll be maintained as part of a Kubernetes orchestrated virtual containerized system. The webpages we've read to research this will have been served off high-availability load-balanced virtual server clusters, and the music-streaming service entertaining us while we write will be from a similar server farm. The list goes on.

This is very much the commercial end of our virtual world, where complexity is abstracted away behind automated software layers for easier management. As virtual technology advances into the GPU realm it's now orchestrating game-streaming services and enterprise-accelerated 3D desktops. But even on your personal machines this same abstraction can help you manage your own suite of virtual machines for running and testing software from Linux servers to old Windows builds, DOS games and more. So let's look at the tools being used, how you can run virtualized machines, and how the virtual technology extends to GPUs.

NEIL MOHR

© GETTY IMAGES

E AWARE, IT'S A VIRTUAL WORLD AFTER ALL


Oracle VM VirtualBox Manager
File Machine Help
Ubuntu
Ubuntu test
Mint
Mint 32bit
Tails
Best windows
Windows 7 (Normal)
Windows 7 64bit
WinXP
MSEdge - Win10 (initial)
MSEdge - Win10 Clone
Raaspbian
Powered Off
New Settings Discard Start
Preview
MSEdge - Win10

Create Virtual Machine

Name and operating system

Name: Windows 95

Machine Folder: D:\Virtual_PCs

Type: Microsoft Windows

Version: Windows 95

Memory size

4 MB 16384 MB

64 MB

Hard disk

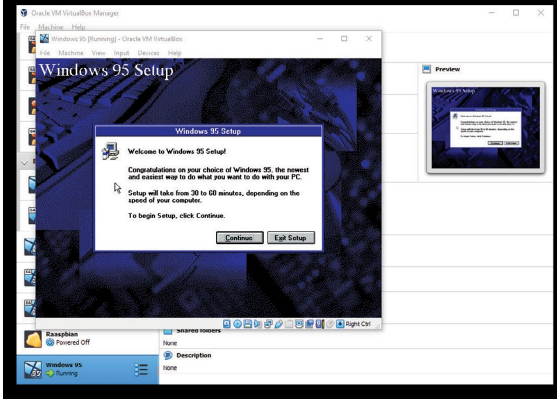
○ Do not add a virtual hard disk

● Create a virtual hard disk now

○ Use an existing virtual hard disk file

MSEdge - Win10-disk002.vdi (Normal, 40.00 GB)

Guided Mode
Create
Cancel
Shared folders
None
Description


Oracle VM VirtualBox Manager
Windows 95 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Windows 95 Setup
Preview
Raaspbian
Powered Off
Windows 95
Running
Right Ctrl

Windows 95 Setup

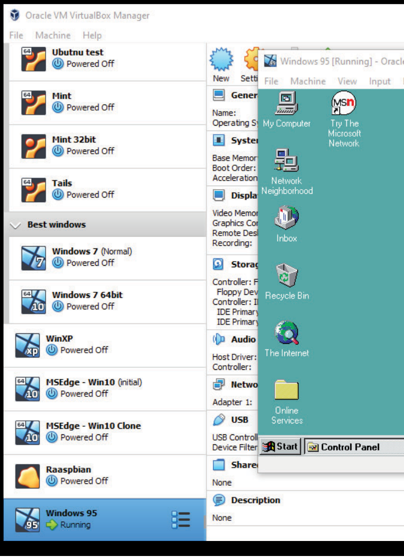
Welcome to Windows 95 Setup!

Congratulations on your choice of Windows 95, the newest and easiest way to do what you want to do with your PC.

Setup will take from 30 to 60 minutes, depending on the speed of your computer.

To begin Setup, click Continue.

Continue
Exit Setup


Oracle VM VirtualBox Manager
File Machine Help
Ubuntu test
Mint
Mint 32bit
Tails
Best windows
Windows 7 (Normal)
Windows 7 64bit
WinXP
MSEdge - Win10 (initial)
MSEdge - Win10 Clone
Raaspbian
Powered Off
Windows 95
Running
Windows 95 [Running] - Oracle
File Machine View Input
My Computer
Try The Microsoft Network
Network Neighborhood
Inbox
Recycle Bin
The Internet
Online Services
Start
Control Panel
General
System
Display
Storage
Audio
Network
USB
Shared
None
Description
None

Top left: **It's hard to contain yourself when moving those sliders, but less is more when it comes to legacy systems.**

Bottom left: **60 minutes you say? Eat my virtual dust!**

© ORACLE VM VIRTUALBOX MANAGER

THE KEY TO VIRTUALIZATION success is ultimately financial, and by financial we mean laziness. Banks of virtual servers can be spun up on demand and dismissed when no longer required. This makes system-administration jobs easier but means that services can scale easily—up and down—depending on demand. This minimizes overheads and can ultimately be made an automatic process.

While this technology might be first aimed at 22-core Xeon servers, your Intel Core i5 or AMD Ryzen still packs the same hardware-virtualization technology as those server systems. While we might not be running systems on quite the same level, we're still going to reap the advantages both from the hardware and the open-source software development.

Long-term readers might recall we ran a VirtualBox guide back in 2018. This covered v5.2 of VirtualBox, but since then the v6.0 release happened, and at the end of 2019 v6.1 was released. A major reason was the integration into the Oracle Cloud service alongside a GUI overhaul, but another addition was the shift to the obscurely named VBoxSVGA (also VMSVGA) support.

VMSVGA stands for VMware SVGA (the default for Linux) and is using a VMware-developed display driver, which is more efficient than the old VirtualBox VBoxVGA driver and still faster than the more recent VBoxSVGA driver (Windows default). Both support OpenGL 2.1 and DirectX 8/9 acceleration with Windows once you've installed the VirtualBox additions.

There used to be a system called PCI Passthrough—we'll talk about this in another context later—which was a hack that "passed" PCIe transfers from a spare GPU "through" to the virtual machine itself. It gave a suitable VirtualBox VM near full-speed GPU acceleration but was more of a workaround hack rather than a true virtualized solution. It was also hardware-inefficient, as the GPU had to be dedicated to a single guest VM and couldn't be used by the local host, and it had security issues. So this feature was removed with the v6.0 release onwards, while the old VBoxVGA driver option was removed with v6.1, apart from some exceptions.

VIRTUALLY OLD

To get acquainted with VirtualBox 6.1 let's get a legacy Windows 95 guest system up and running. Try and think in terms of mid-90s PCs, so memory and storage are all in paltry megabytes. We're sure you've got an old Windows 95 install CD knocking around in the attic. Ideally you'll want to image this as an ISO image—head to imgburn.com, the classic Windows-based tool for imaging optical discs. Remember, Windows 95 is still copyright to Microsoft, so it's illegal to go for easy-to-download pre-built Windows 95 OSR2 ISO images on that internet.

Cast your mind back 25 years and remember that original Windows 95 install discs couldn't boot! The olden days certainly were terrible. It presumed either an install of Windows 3.1 would be in place or you had a floppy boot disk to hand. You can again get an image of a suitable boot disk at allbootdisks.com/download/95.html. For Windows 95a grab that IMG file, but if you're using the "latest" Windows 95 OSR2 release then the 95b.img is super.

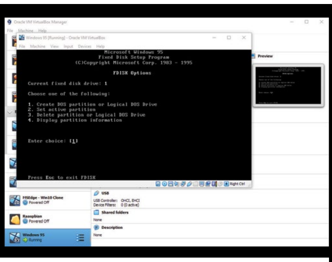
With images to hand, we can start creating a suitable virtual guest in VirtualBox. Click "New > name this Windows 95," and this will set the memory to a sensible 64MB. Creating a virtual drive, Windows 95 uses the FAT16 filesystem, so the maximum drive size is 2GB—this is auto selected.

At this point VirtualBox creates the guest, but we need to tweak the settings, so click the "Settings" button. VirtualBox these days will select sane defaults that are worth going over. Windows 95 can only use a single core processor, and you'll need to keep hardware virtualization off (it'll work but can throw up issues/blue screens of the death-type during use), as well as 3D or 2D—this should all be auto selected. Similarly the older PIIX3 chipset, PS/2 Mouse and SoundBlaster audio will be automatically chosen.

Under "Storage" you'll need to point the "Floppy Device" to your floppy image and the "Optical Device" to your Windows 95 ISO image, both under the "Storage" section. If your files are "raw" IMG files, when selecting these change the filetype in the "Explorer" dialog. Click "OK" to save the settings.

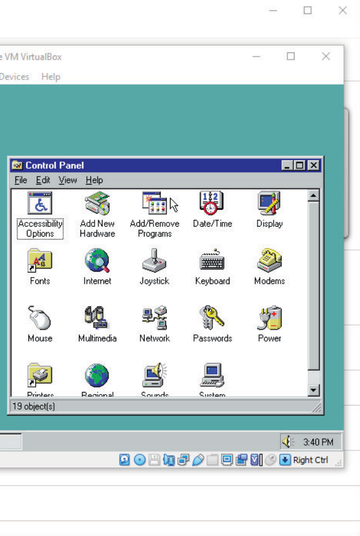
Hit "Start," and wrangle Windows 95 on this system. The floppy image should boot you to an A:\> prompt. If not, ensure you have a correct floppy boot-disk image, the virtual machine has a floppy device attached and it's pointing at the correct file.

The virtual guest will "capture" the mouse and keyboard input, press the right Ctrl key to jump back out. Type "fdisk", press Return, choose "Large Disk" support so we can make use of that HUGE 2GB of space (oh the luxury, you lucky millennials), select "1 > 1 > Y" and Escape. That's creating



```
Microsoft Windows 95
Fixed Disk Setup Program
(C)Copyright Microsoft Corp. 1983 - 1995

FDISK Options

Current fixed disk drive: 1

Choose one of the following:

1. Create DOS partition or Logical DOS Drive
2. Set active partition
3. Delete partition or Logical DOS Drive
4. Display partition information


Enter choice: [1]




Press Esc to exit FDISK
```

Oracle VM VirtualBox Manager
File Machine Help
Windows 95 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Preview
Right Ctrl
MSEdge - Win10 Clone
Powered Off
Raspbian
Powered Off
Windows 95
Running
USB
USB Controller: OHCI, EHCI
Device Filters: 0 (0 active)
Shared folders
None
Description
None



Top left: **The awful old world of DOS partitions.**

Bottom left: **Now relive those glory days of missing drivers and blue screens of death.**

an active primary partition using all the space. Select "Input > Keyboard > Insert Ctrl-Alt-Del" to force a reboot.

Now format the C: drive with "FORMAT C." Time to install the Windows. Typically the optical drive will be R:, so type "CD R:\" and "R:" to switch to it—the drive letter is displayed when the driver starts as the floppy boots. We'll cover installing off the CD-ROM; this can cause headaches down the line, as driver updates will constantly be looking for the CD drive, which can change or not be mounted at all. To avoid that you can install all the install-files over with "xcopy R:\ C:\INSTALL\ /S," and install it from there.

Either way, type "setup" to kick things off. Don't forget your legit Windows 95 licence key. When prompted, select "Network and Sound cards." Let the install run—it's super quick weirdly. Before rebooting select "Devices > Floppy" and remove the bootdisk. It's also worth going into "System" and moving the boot order of the hard drive before the optical drive—if it needs to install drivers, check the next section first…

Now, if you're running an AMD Ryzen system, when Windows 95 reboots you'll likely run into a hilarious Windows bug that gives you an "Initializing Device IOS: Windows Protection Error" error of death message. This can occur on any AMD system faster than 350MHz (Outrageous!) and potentially Intel CPUs over 2.1GHz. Head to http://lonecrusader.x10host.com/fix95cpu.html, download and extract the Fix95CPU patch. This implements a Microsoft solution via an ISO file. With the Windows 95 guest off, add the FIX95CPU.ISO file and boot. Skip the readme and run the patch, then remove the ISO file and everything should boot fine. Remember to replace the Win95 ISO and adjust the boot order for driver installs.

We don't remember Windows 95 being this bad? We're probably remembering Windows 98, where many, many issues had been fixed. The bad news is you're probably stuck with 640x480 in 16 colors, as there's no official fix for this with VirtualBox. Windows 95 was never a real target for VirtualBox guests—you could track down the defunct SciTech Nucleus Driver ISO, which can open 1024x768 resolutions at 32-bit color, which is proper fancy.

The good news is you can get online with some minor tweaks. Right-click "Network Neighbors icon > Properties." First add in the "Microsoft > TCP/IP Protocol," then remove "Client for NetWare" (silly Novell), the NetBEUI and IPX protocols. Windows 95 will want to reinstall drivers from the CD-ROM, so check that the drive letter matches in the pulldown. After a reboot, you can run "winipcfg" to check you have an IP address assigned. We added our router IP to the" Gateway TCP Properties," which seemed to help.

You can jump on to websites, but you'll find the ancient Internet Explorer lacking JavaScript and modern HTML5 to be utterly useless, but it's all a bit of fun! Perhaps try and get a suitable build of Netscape, but otherwise we're up and running!

REMOTE ACCESS

A neat trick we like to use with VirtualBox is its ability to enable a Remote Display Server—much like remote desktop it enables someone on the network to remotely access a running virtual machine. If you use it alongside the "headless" and Detachable VM modes, you can make a guest machine of any type you like, available to anyone able to access your local network with a suitable RDP client. All you need is the IP address of the host PC; on a Windows PC press

Using Intel GVT-g

Of course it's only available on Linux— an Ubuntu 20.04 install will do—and the official Intel guide (http://bit.ly/maxpcgvt) is pretty deep. The official Arch guide (http://bit.ly/maxpcarch) can be followed, but requires a good few asides for the uninitiated. The most user-friendly guide we spotted is at http://blog.tmm.cx. The four-step process covers:

CONFIGURING THE HOST MACHINE

Largely this involves installing the software then configuring the kernel and bootloader. The Linux kernel has KVM built directly into it—this is the Kernel Virtual Machine, so there are standard libraries (libvirt, virt-manager) for initiating virtual machines. Alongside this is Qemu, the standard hardware-emulator system that can emulate everything from ARM to x86. Also required is a SPICE server that helps manage virtual desktops, plus VirtIO drivers for Windows. The kernel needs a few parameters set at boot time so that it knows to expect GVT messages and to have the correct modules loaded.

CREATING THE VIRTUAL GPU

If everything is working, this is a case of creating a Linux kernel UUID (universally unique identifier) for the device and appending it to the device config, ensuring it has enough VRAM to work in the first place. Once that's done, you create a Linux systemd service to ensure that it's started each time the system boots up.

SETTING UP A WINDOWS VM

This uses Qemu/KVM to install the Windows guest with CPU passthrough and use the VirtIO drivers. Once up and running the SPICE server additions can be installed. When the basic Windows 10 VM is set, the configuration needs to be edited to support the virtual GVT-g GPU. This involves editing the rather large XML config file.

ENABLING GVT-g

At this point, when the virtual machine is started it'll almost be like Windows 95, with software-rendering limiting the resolution. Windows now requires the correct Intel DCH graphics drivers, tweaking the system to support a wider range of resolutions and checking that DirectX 12 is supported.

Window key, type "cmd", then type "ipconfig" and read off the IPv4 address.

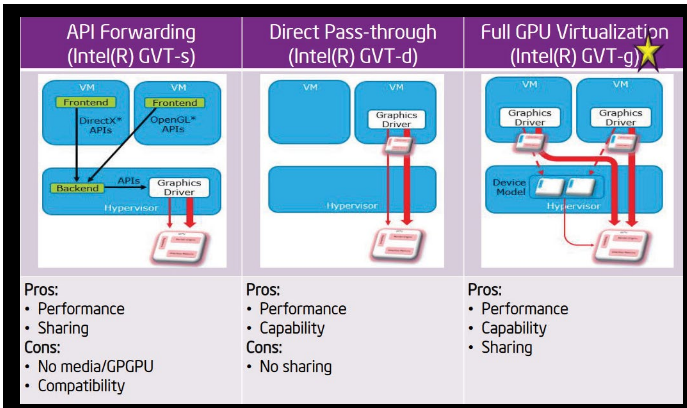
We're going to presume that you have your VM guest already set up, so we'll tweak an existing VM. In VirtualBox select the VM you're interested in, then click "Settings," select "Display > Remote Display > Enable Server."

You'll see that the default port is 3389. The quick among you may have realized that this is the default Windows RDP port, so if you happen to use RDP already you'll certainly want to change the port. It would be wise to do so anyway to avoid head-scratching conflicts down the line. Additionally, only one running VM guest can utilize a specific port at a time on a system, so if you plan on using this with more than one VM guest this will need to be changed for each. Oracle recommends ports between 5000 and 5050, so start with 5000 and increment.

Once you've selected that, on the same PC press the Windows key and type "RDP < Run Remote Desktop Connection." As you're on the same PC as the virtual guest, in the RDP window use 127.0.0.1:5000 (this is the local loopback address and your port), it should connect. On a remote PC on the same network you'd do the same but type "<ipv4 address>:5000" and click "Connect." From a command prompt you can type "mstsc -v <ipv4 address>:5000" for the same result.

As a quick aside, Oracle supports limited remote USB access. A VirtualBox guest can access the USB devices of the remote computer on which the VRDP data is being displayed, just as if the USB devices are connected to the actual host. The trouble is Oracle only provides a Linux RDP client capable of this.

If you're interested in remote access, also know about Headless mode. This launches the VM without a window, just for remote access. It can be launched from the GUI by clicking the down arrow next to the Start button.



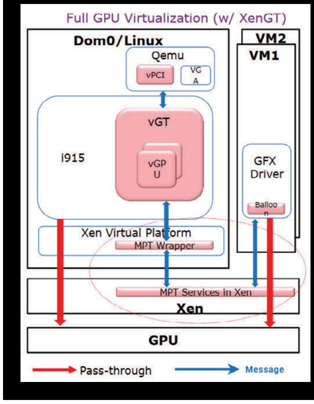
Pros:
- Performance
- Sharing

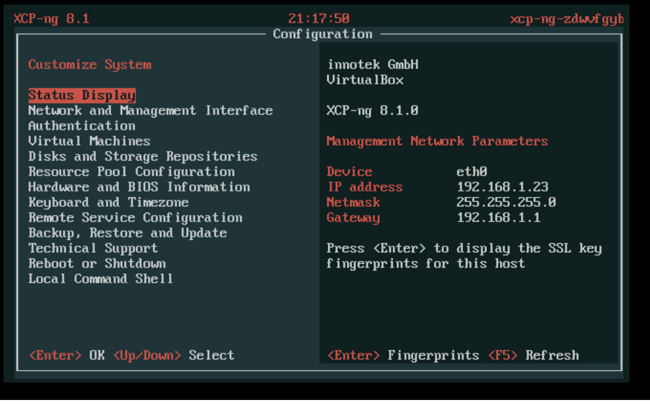
Cons:
- No media/GPGPU
- Compatibility

Pros:
- Performance
- Capability

Cons:
- No sharing

Pros:
- Performance
- Capability
- Sharing





```
XCP-ng 8.1                          21:17:50                    xcp-ng-zdwvfgyb
                              Configuration

  Customize System                           innotek GmbH
                                             VirtualBox
  Status Display
  Network and Management Interface          XCP-ng 8.1.0
  Authentication
  Virtual Machines                           Management Network Parameters
  Disks and Storage Repositories
  Resource Pool Configuration                Device          eth0
  Hardware and BIOS Information              IP address      192.168.1.23
  Keyboard and Timezone                      Netmask         255.255.255.0
  Remote Service Configuration               Gateway         192.168.1.1
  Backup, Restore and Update
  Technical Support                          Press <Enter> to display the SSL key
  Reboot or Shutdown                         fingerprints for this host
  Local Command Shell



  <Enter> OK <Up/Down> Select                <Enter> Fingerprints <F5> Refresh
```

Top left: **These are the three main modes for virtualizing GPU access and how they work.**

Bottom left: **A more in-depth look at how the Intel GTV-g system works along with the Xen architecture.**

Bottom: **The XCP-ng server up and running in all its DOS GUI glory.**

VIRTUAL GRAPHICS

The last big area in virtualization that needed tackling was GPUs. It wasn't until after the mid-2010s that full virtualization solutions started to appear, but only aimed at enterprise and professional markets. Services like Nvidia GRID, which it uses to power its GeForce NOW service, and AMD Radeon MxGPU enable GPU and compute capabilities to be delivered from data centers to networked workstations in a secured environment. Due to the price mark-up these specialist areas command, it means that much of this technology hasn't been opened up to consumers.

One such area that has is PCI passthrough. It's delivered by the virtualization software using generic GPU hardware and is more a hack than offering any true virtualization abstraction. It offers high performance and is simple to implement, but is very wasteful with hardware, as only one guest OS can utilize the GPU, and the host is locked out too.

Another generic software workaround is called API forwarding or API remoting. Using a special virtual GPU driver on the guest, any 3D calls to the GPU API are forwarded to the host system, where they're run on the real GPU hardware. The advantage is that multiple guests can access the GPU. The downside is efficiency—performance at best is 80 percent but can be as low as 15 percent, depending on what calls are being run—and there are security concerns, as memory could be shared between guests for efficiency. It does have the advantage that calls can be network routed for added flexibility.

The ideal fully virtualized solution should offer full API compatibility i.e. OpenGL 4.x, DirectX 11/12, OpenCL and CUDA support, with high performance and shared hardware between guests and hosts. This has been the final sticking point for the virtual world, even considering the prodigious amounts of money floating around the likes of Nvidia, AMD, and Intel.

Nvidia offers a range of virtualization solutions, including Virtual Compute Server (vCS), Quadro Virtual Data Center Workstation (vDWS), GRID Virtual PC (vPC), and Virtual vApps. AMD has its AMD MxGPU technology to deliver up to 16 VMs per GPU over a network. This arrived in 2017 with its Radeon Instinct line that was aimed at deep-learning networked solutions. But these are all enterprise and professional-class solutions.

The only widely available consumer GPU virtualization technology is from Intel, under its Intel Graphics Virtualization Technology (GVT). Initial versions of this were released by Intel over 2014/2015. It's been rolled out in three forms and should work with 5th-generation (Broadwell) processors onwards on Intel's integrated graphics.

Intel offers GVT-d, GVT-s, and GVT-g. The first, -d, is direct passthrough, which is less than ideal. For single VMs use it's worth considering, but using the onboard Intel graphics as your primary display won't be an option. The "-s" stands for "Shared" and enables multiple virtual guest access to a single physical GPU via API forwarding. It's more flexible for multi-guest use, but there's no GPGPU support and again no host access.

The solution everyone should be interested in is GVT-g and its full GPU virtualization, full API support, near-full performance, and shared access. The Intel virtual driver supports up to seven virtual guests on top of the host.

The bad news is there's no Windows host support for this at all. We guess this is because it involves the kernel to be updated and configured to handle the redirected virtual calls, and Microsoft has no interest in investing resources to make this viable for consumers to use.

There is a Linux host solution (because of course there is), but setting this up is, erm, quite involved (see the boxout), but once done you get near full-speed GPU acceleration on Ubuntu and Windows 7/8/10 Guest OS. So it is of genuine use for developers who need access to multiple OSes.

VIRTUAL ORCHESTRATION

While hunting around for an "easy" virtualization solution that supported the various GPU passthrough modes we stumbled upon the http://xcp-ng.org project. This is a Turnkey (read: easy to install) server virtualization solution, based on the industry standard open source Linux XenProject.org.

If you have dedicated hardware available and you're wanting to run and manage virtual machines, then this is well worth a look, but keep in mind it's a server installation, so it's set to take over the entire machine/install drive and be remote-administered. If you have a spare drive then you could swap out the existing boot drive on a machine and install this to give it a go. Once it's set up and running (that can be done in five minutes) it's designed to run headless (without a monitor) so can be entirely managed from a web interface, but for you Windows types the community maintains an unofficial Windows XCP-ng Center https://github.com/xcp-ng/xenadmin at v20.04 as of April 2020.

The good news for us is that if you have the right hardware, XCP-ng can support GPU passthrough on virtual guests. For Intel graphics that's GVT-p and GVT-g; if you have "dumb" consumer GPUs it'll provide direct passthrough, while if you have access to "pro" cards like Nvidia Quadro or AMD MxGPU-enabled Radeon Pro/FirePro cards, full GPU virtualization can be utilized.

If you want to try a full hypervisor solution, we'll give you the key pointers on how to get it installed and up and running with GPU passthrough. But you're going to have to figure out the minor steps yourself—it's a professional solution, so be prepared to read one heck of a manual.

Head to https://xcp-ng.org/#easy-to-install and grab the install ISO, write this to a USB stick and boot your spare "server" system with it. Please ensure you know the correct blank drive to install it to—you can also use this to store the virtual machines. When asked, use the local files and ignore the add-ons. You'll be asked to create a password, remember this, as you need it to remote-log in. If all goes smoothly it'll reboot to a classic DOS-style XCP-ng main menu that tells you the IP address of the PC, but ignore this.

On another networked Windows PC, download the latest build of XCP-ng Center and install it. Ensure your XCP-ng server is running on the same network, and choose "Add Server." Enter its IP address and the password you created for it. We'd strongly suggest you use a network shared folder to store your ISO images for installing virtualized guests. Oddly we had one up and running already. Select the server, click "New Storage > ISO Library > Windows File Sharing." You'll need the network path to your server //<server name>/<iso folder> if you have set for public access use the username guest, otherwise enter the access credentials.

Use "New VM" to create a new virtualized guest. We're going with Windows 10—at this point it's very much like VirtualBox to create a VM, but "Installation Media" provides a drop-down of your stored networked ISO files. We'd add the GPU later, because if there are any issues you'll end up with a blank screen. Before starting the VM you need it to boot the DVD image. select the "VM > General > Properties > Boot options" and move the DVD drive to the top, then hit "OK." Start the VM and switch to the "Console" tab to interact with the VM and install your OS!

So there we are, a quick tour on the current virtual world, from one-off virtual guests in VirtualBox to super-orchestated guests using Xen and XCP-ng alongside GPU virtualization. ⏻

Hardware acceleration

Any processor made in the last 15 years (since the introduction of the Intel Core range) will likely have some form of hardware virtualization. AMD joined Intel a year later in 2006, adding the first hardware extensions to its Athlon 64 "Orleans" models onwards and Phenom II processors.

Early on these features were sometimes disabled in the BIOS, and even today there can be BIOS virtualization options tucked away.

Hardware virtualization implements internal hardware systems that enable the processor to faster switch the processor state between serving the host OS and virtual guest. The hardware extensions enable the hypervisor to effectively switch the whole CPU context between the local OS and hypervisor VM code, to register interrupt handling, instruction calls, and critically handling the remapping of memory calls alongside I/O and DMA access.

Both AMD and Intel introduced a range of processor features. The initial features, called Intel-x and AMD-v, provide instructions to rapidly switch the guest to a privileged state to run trapped calls. AMD also added Rapid Virtualization Indexing, followed by Intel EPT that virtualizes memory page-table look-ups. Benchmarks show that these increase kernel-level performance to five fold depending on the workload.

AMD-Vi and Intel VT-d provide an I/O memory management unit also called PCI passthrough. It enables the guest OS to access hardware seemingly directly, via a translation table on the host. Both processor and motherboard need to support the feature and you may need to activate this in the BIOS.

Building on the I/O features, virtual interrupt support was added shortly after IOMMU. AMD with its AVIC (Advanced Virtual Interrupt Controller) and Intel with its APICv. Both are designed to route virtual interrupts to the correct real CPU.

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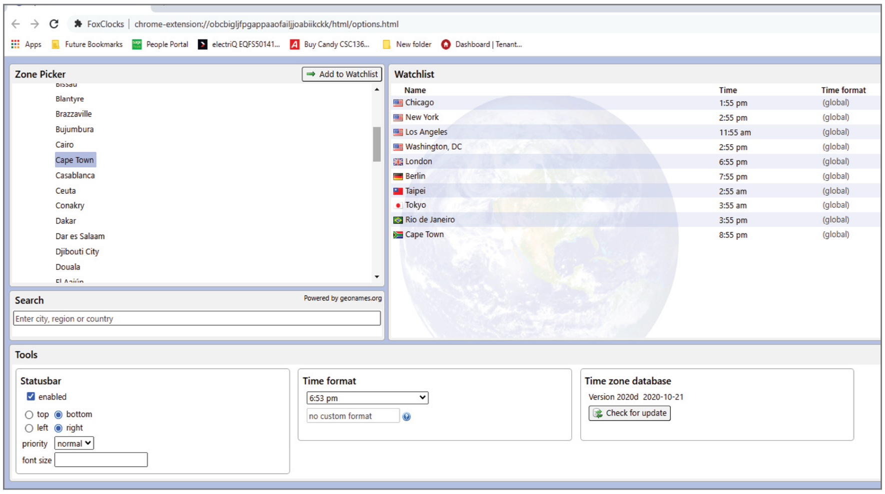
forums.pcgamer.com

PC GAMER

HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

TIP OF THE MONTH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Apps
Future Bookmarks
People Portal
electriQ EQFS50141...
Buy Candy CSC136...
New folder
Dashboard | Tenant...
Zone Picker
Add to Watchlist
Blantyre
Brazzaville
Bujumbura
Cairo
Cape Town
Casablanca
Ceuta
Conakry
Dakar
Dar es Salaam
Djibouti City
Douala
Search
Powered by geonames.org
Enter city, region or country
Tools
Check for update

Watchlist

Name	Time	Time format
Chicago	1:55 pm	(global)
New York	2:55 pm	(global)
Los Angeles	11:55 am	(global)
Washington, DC	2:55 pm	(global)
London	6:55 pm	(global)
Berlin	7:55 pm	(global)
Taipei	2:55 am	(global)
Tokyo	3:55 am	(global)
Rio de Janeiro	3:55 pm	(global)
Cape Town	8:55 pm	(global)

Statusbar
☑ enabled
○ top ● bottom
○ left ● right
priority: normal
font size:

Time format
6:53 pm
no custom format

Time zone database
Version 2020d 2020-10-21

KEEP TIME WITH FOXCLOCKS

Like us, your work might involve interacting with colleagues and contacts both at home and abroad. FoxClocks is a handy Chrome extension that enables you to keep a variety of live world clocks in your toolbar—perfect for a quick check as to whether a phone call or email is going to be arriving at an appropriate time. Never disturb a faraway colleague while they are sleeping again!

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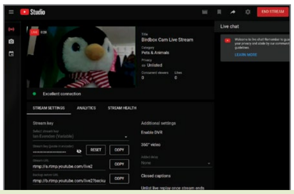
MAKE – USE – CREATE

60
Read part two of our cable sleeving tutorial



64
Stream from a birdbox with a Raspberry Pi

68
Move your rig into this epic Razer ITX chassis

CHRISTIAN GUYTON
STAFF WRITER

SHADY SUBSCRIPTIONS

Netflix is raising its prices again. The standard subscription is being yoinked up to $14 a month, with the premium subscription rising to $18. It's another incremental increase to the selection of regular payments coming out of my bank account, keeping the services I use ticking over.

That list seems to be getting increasingly long. Amazon Prime, Spotify, broadband, a contract on a shiny new Google Pixel phone... So with new home consoles looming, demanding a cut of my dwindling finances for paid online services, I've never been more glad to be a PC gamer.

The new offerings from Sony and Microsoft might appear to be a good price-to-performance proposition on paper, but between paid online support and $70+ games, I couldn't bring myself to purchase one. Xbox Game Pass might be decent value if I had all day to play games, but I can pick up a lot of those titles for a fraction of their price in the big biannual Steam sales anyway.

I've got nothing against console gamers. I own a Switch (and my fiancé has a Switch Lite), but I don't feel the need to shell out for the online subscription. I can visit my partner's island in *Animal Crossing* without needing to spend a penny more than the price of the game. And that's how it should be.

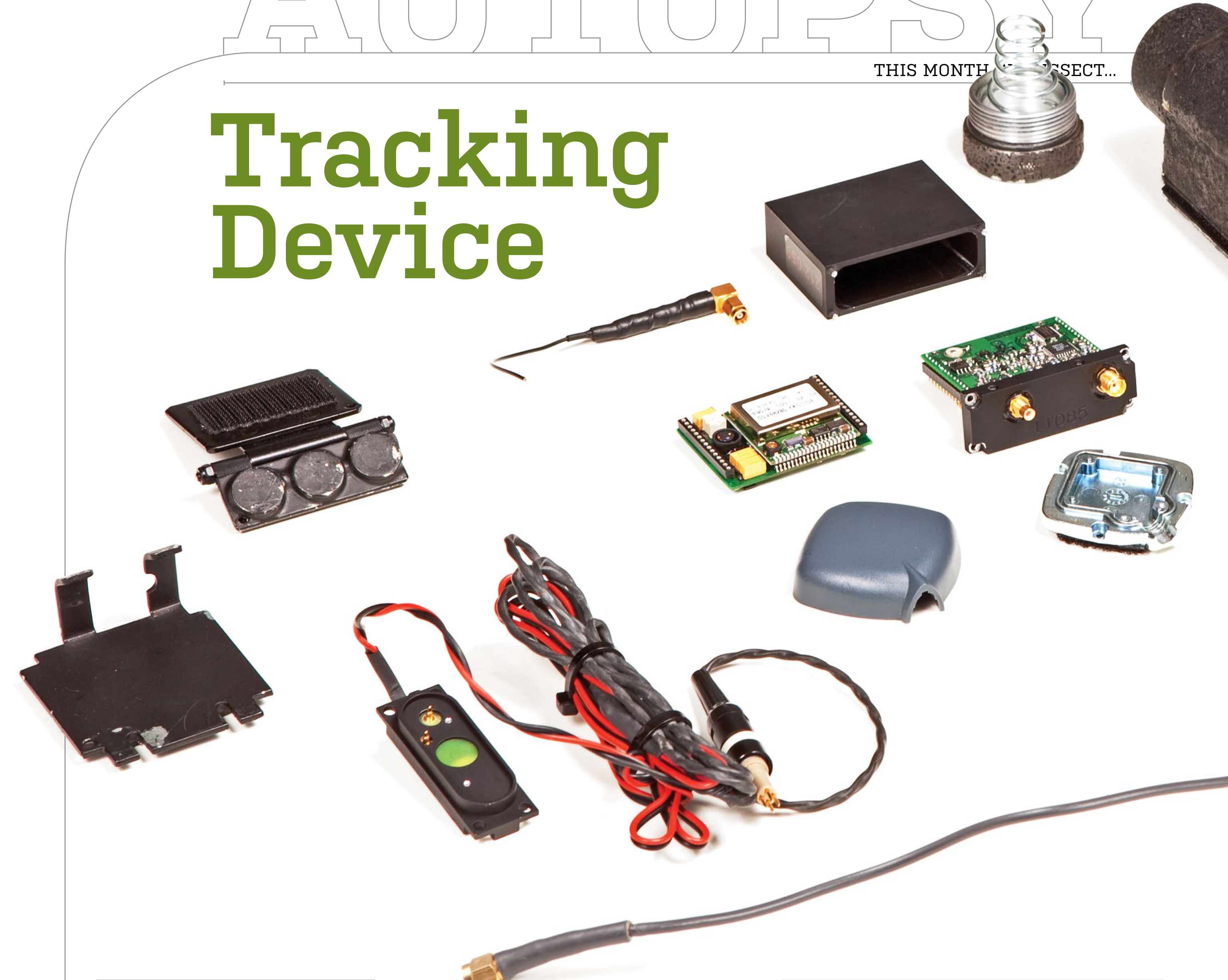
↘ submit your How To project idea to: comments@maximumpc.com

IFIXIT presents:

AUTOPSY

THIS MONTH WE DISSECT...

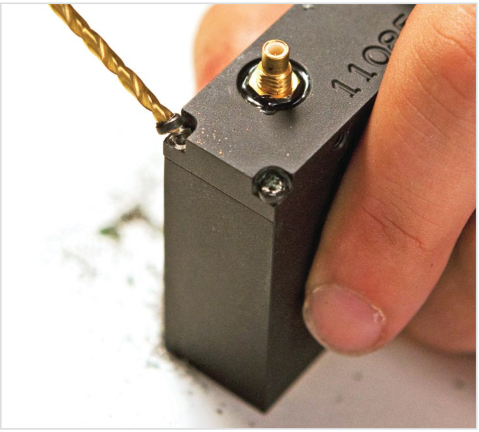
Tracking Device



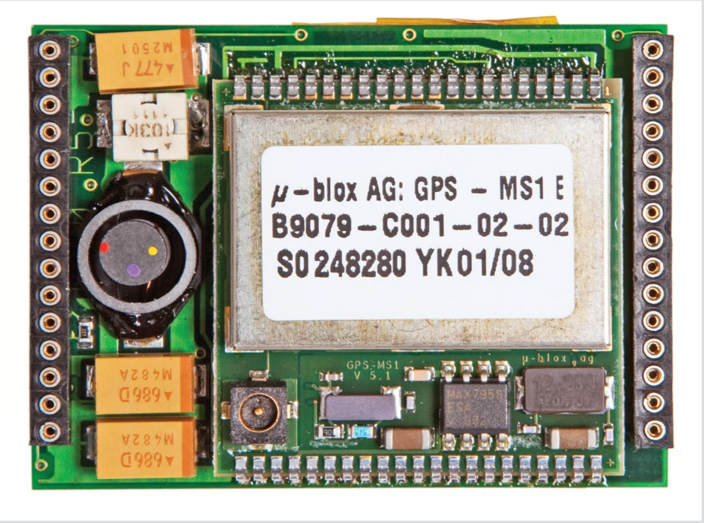
About iFixit

iFixit is a global community of tinkerers dedicated to helping people fix things through free online repair manuals and teardowns. iFixit believes that everyone has the right to maintain and repair their own products. To learn more, visit www.ifixit.com.

The screws were coated with so much threadlocker that we had to break out the power drill and eliminate the screw heads.



This μ-blox GPS processing module was released way back on June 29, 1999!



BACKGROUND

We've partnered with *WIRED* to bring you a peek inside an FBI tracking device, similar to the one Yasir Afifi found on his car.

Disclaimer: We love the FBI. We've worked with them on several occasions to fight crime and locate criminals. We've helped them with instructions on gaining entry into certain devices. We have nothing against them.

MAJOR TECH SPECS

- Battery pack
- GPS antenna
- XEMICS XE1201 Ultra-low-power single-chip transceiver
- RFM RF1172 SAW (surface-acoustic-wave) filter
- Magnetic mounting bracket

KEY FINDINGS

- We finally have one of these on the teardown table! The components of the system are all attached to a vehicle with powerful magnets. What tech keeps this device powered? Let's remove the battery pack's end cap. It's powered by four lithium-thionyl chloride D-cell batteries. Each cell is good for 13,000 mAh, about double the capacity of the iPad 2's battery. The cells are suited to low-draw applications where longevity is needed, with a service life of 10-20 years.
- To begin tearing the device apart, we detach the two antennas from their screw-in mounts. The shorter antenna is responsible for transmitting the location signal to transponders that the FBI would use to find someone. The larger antenna is for receiving GPS signals from satellites. Removing a few Phillips screws lets us access the innards of the GPS antenna. It's attached to its bracket with Velcro.
- Let's turn our attention back to the transmitter/receiver module. A few screws are all that remain between us and the innards of this invasive device. The rear cover is simply a method to connect the module to power. Presumably, different batteries can be connected to make the tracking device more universally installable.
- To get to the brains of the module, we focus on the other end cap. The FBI really doesn't want anyone tampering with the innards of their tracking devices. The screws are coated with so much threadlocker that we have to break out the power drill and eliminate the screw heads.
- Upon drilling out all the screw heads, the outer case slides off the transmitter/receiver assembly. The two modules can be split apart to examine their circuits. A small blue wire connects the GPS antenna to the GPS receiver board. After disconnecting the GPS board, we can take a closer look.
- The module providing the GPS signal-processing is a μ-blox GPS-MS1 that's ancient in the realm of modern electronics. It features 0.125MB of SRAM and 1MB of flash memory. The imperfect alignment of the SMD components on the board indicates that the FBI hand-soldered them.
- The larger of the two boards contains the connections for both antennas and is responsible for the RF side of the tracking device. The XE1201 chip allows for data transmission and data reception, while the RF1172 provides front-end selectivity in 433.92MHz receivers.
- Repairability Score: -10 out of 10 (10 is easiest to repair). The FBI will find you if you find their tracking device. You cannot choose to not be tracked by the FBI. You can legally be tracked by one of these units. We'll be right back...

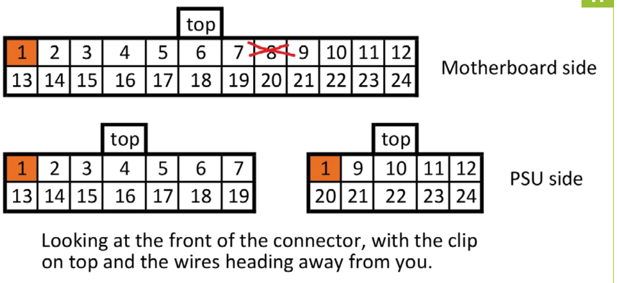
Cable Sleeving Tutorial Part 2

YOU'LL NEED THIS

CABLE SLEEVING TUTORIAL PART 1
Maximum PC Vol 25 No 12.
Patience.

LAST ISSUE we went through the main tools that you're going to need to start creating your very own custom power-supply cabling. Custom cables are by far and away one of the best ways you can make your system shine. You can of course opt to buy those from a 3rd party, such as CableMod, and even some of the PSU manufacturers offer their own sets of custom-sleeved cables, but to really make a build pop, there's nothing quite like making your own. If you do, you can control every single aspect of that process, from the sleeving colors used, to the length, to whether or not to integrate your own combs—practically everything.

Now that you've got the basic tools at hand and know how they operate, it's time to put these bad boys to work and make some beautiful cables for your perfect PC! It's important to remember two things when you're doing this: Firstly, you're going to need a ton of patience; and more importantly, practice makes perfect. Don't beat yourself up if it doesn't go perfectly the first time you do it, and remember to take your time, double-check everything, and make sure your pin-outs are going to the right place. Once that's all wrapped up you'll have your very own kick-ass set of cables for your perfect rig. **–DAVE ALCOCK & ZAK STOREY**



Motherboard side:

1	2	3	4	5	6	7	~~8~~	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24

PSU side:

1	2	3	4	5	6	7
13	14	15	16	17	18	19

1	9	10	11	12
20	21	22	23	24

Looking at the front of the connector, with the clip on top and the wires heading away from you.

1 PIN OUTS OR PRE-MADE?

Firstly, figure out if you're going to be sleeving the cables that came with your power supply, or if you're making your own from scratch. If it's the former, you can skip many of these steps and head straight to step 7. Otherwise you can start by making the pin-out, either by physically following the cables, searching online, or—the far better way—using a multimeter in continuity mode, and touching each cable at either end until it shows that it's a circuit that will tell you exactly where each pin/cable goes.

2 24-PIN MOTHERBOARD POWER CABLE

[**Image A**] This is an example of a pin-out for a standard 24-pin motherboard ATX cable. In modern-day power supplies, pin eight is no longer required, so you'll only ever have 23 pins or cables in the cable itself. This means that you'll likely have to use a Y cable as is shown with pin number one, and the corresponding pins on the two PSU side connectors. We'll go through how to deal with Y cables in the next issue as they are a little more complex when it comes to making and sleeving them.

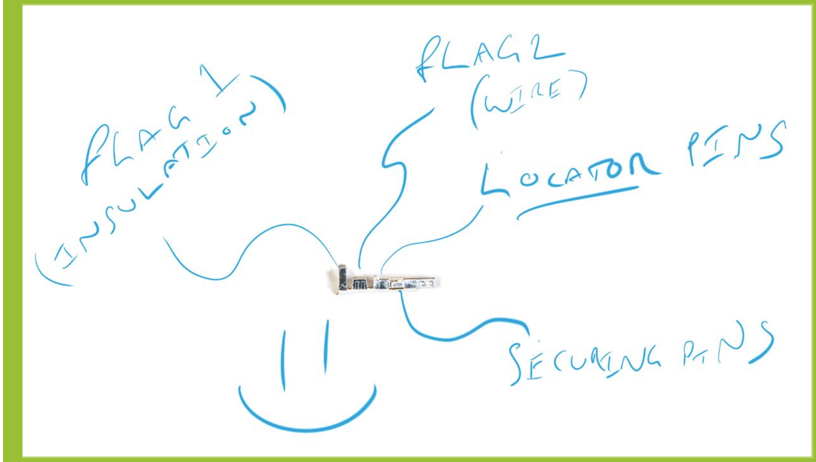
›› When creating your own cables, you'll also need to make a pin-out, unless you're just doing extensions, between the old included cables and your components. Extensions are a one-to-one layout, so pin one will go to pin one, pin nine will go to pin nine, and so on. It really is easy to make a pin-out diagram, so don't worry. We often just use Excel or a similar program, and simply use numbers to associate the pins from the 24-pin connector with the PSU connector.

›› It's worth noting that many PSUs come with capacitors added to the cables themselves to keep electrical ripple down across the wires. These are often just there to make the power supplies look better in reviews and hit arbitrary number targets—the reality is that they're not really necessary at all and can often just be cut off.

›› Having said that, make sure you research your PSU before doing so, as not all power supplies are created equal, and so you're better off just double-checking that before butchering those cables up. Quite often after-market cables don't have the same capacitors, so if you can find replacement cable kits for the PSU, then usually you're good to go.

3 CABLE TIME

Let's make a cable! [**Image B**] The first thing you're going to need to do is measure the length of the cables that you need. For replacement cables on a modular PSU you will want to measure from the power supply, follow the route you wish the cable to go along inside the chassis, and then to the component you wish to power. Remember that bends add length and that sleeving actually adds mass to the cable as well, so be mindful of this when measuring—multiply your final measurement by a factor of 1.1.



PIN TERMINOLOGY

So here we have a terminal. Both male and female terminals look very similar, the only difference being the female one is larger, so it can fit correctly with the male terminal and make contact completing the circuit. You have four main components you need to be aware of. Flag one, on the far left, is the portion of the terminal that will be crimped onto the plastic insulation of the cable itself. Flag two is the part that will crimped directly on the wire to hold it in place. The locator pins also pin down on the bare wire, and is the maximum point the wire should touch. The securing pins are what hold the cable into the connector itself.

›› With extensions—what we're going to look at here—we're just going to go behind the motherboard tray. A total length of eight inches usually does this comfortably in an ATX chassis. One thing to note, however, is that if you do want a nice curve, you can make the 12 wires on the inside of the bend slightly shorter than the 12 wires on the outside of the curve. You don't need to make them too short—for our example the outside cables would be eight inches, so we will make the inner cables 7.5 inches. There is likely a rather nice formula to find the sizes of internal and external sizes of an arc, but honestly it doesn't need to be an exact science, and we get great results with guestimation. Similar to liquid-cooled tubing, this is where practice and experience help a lot.

4

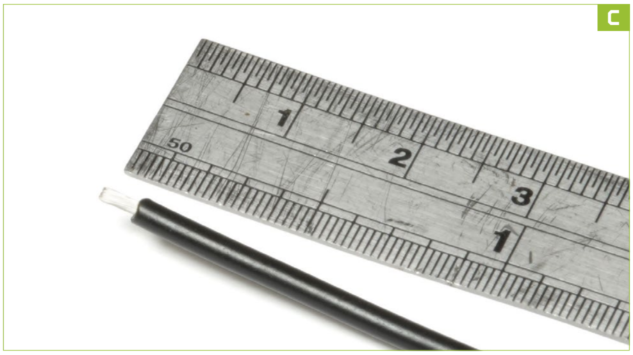
WIRE PREP

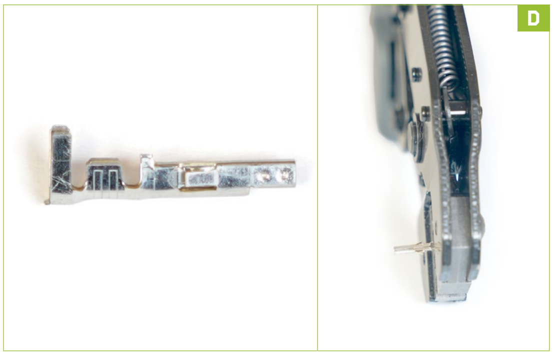
[**Image C**] Once you have measured and cut the wire to length, you're going to want to strip off part of the electrical insulation from it. You only need to take off around 1/8th of an inch, so don't go too crazy, as the terminal needs to grip both the metal of the wire and the insulation on the cable for a perfect crimp. We use Molex-branded ATX pins from www.cable-sleeving.com as they are the best-quality pins we have found, and they crimp a lot better than some of the cheaper options you can find on eBay or elsewhere online.

5

CABLE CRIMPING

[**Image D**] With the wire prepped and ready to go, it's time to get the cable pin on and ready to crimp. Slide the wire into the pin, and make sure the terminal makes contact with both the bare cable and the plastic sleeving. Once that's done it's time to place it inside your cable-crimping tool of choice. When inserting the terminal into the crimping tool, make sure that both the "flags" are inside the tool correctly. The locating pins should be outside of the crimping tool. It is important that you don't crush the locating pins while closing the crimping tool. And again to reiterate that point from earlier, make sure flag one crimps around the insulation of the wire, and flag two crimps around the metal of the wire.


C

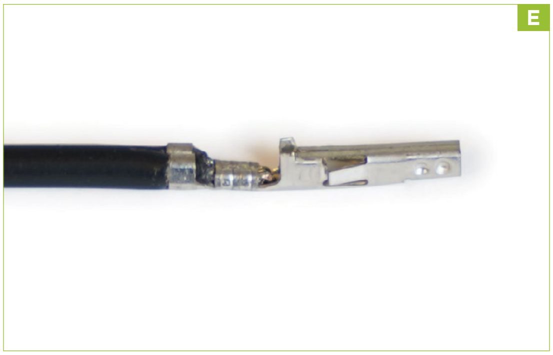

D

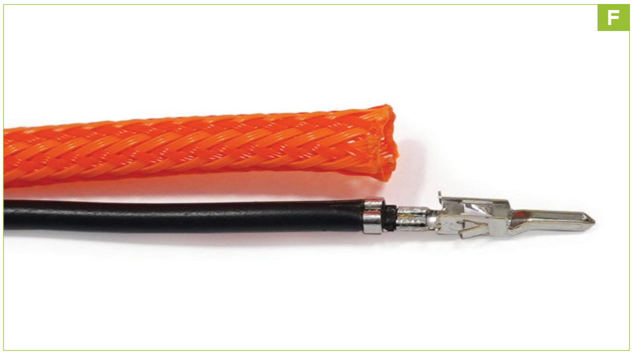
6

THE PERFECT CABLE

[**Image E**] Once you've managed to do all that and crimp the terminal into position on the cable, it should look just like this. Notice that the whole pin is straight, and that it's gripping the correct parts of the cable with the two flags.

›› On top of that, you can see that the locator pins (which lock the terminal into its plastic housing/


E



connector) are not damaged at all, and everything just looks like it's in the correct position. It can take a while to get this right each and every time, but once you've done it enough, you'll be flying through this part of the process—which is good, as you'll be doing this 40-50 times for your build in some cases.

7 TIME FOR SLEEVING

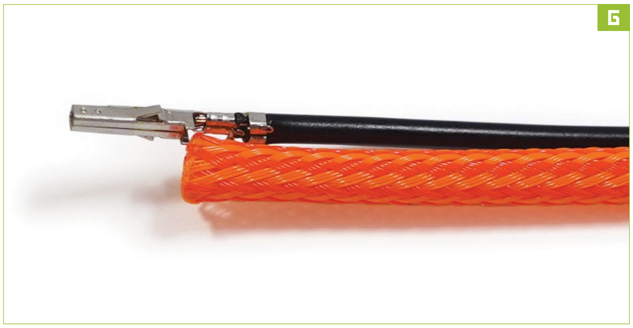
[**Image F**] Going back to the pins for just a second, you are going to need two different types depending on what it is you're making. For instance, in the case of sleeving the cables that come with your power supply, all you'll need are female terminals or pins, as both the power supply end and the parts you'll be powering have male terminals on their power-connection ports.

›› When it comes to extensions you'll need both male and female ATX pins: The male pins for connecting the extension to the original power-supply cable, and female pins once again for connecting to the part you're looking to power.

›› As we're making extensions, we will crimp the other end of the wire with a male pin and start to measure the sleeving. Once the sleeving is cut, the wire is going to be passed through it, and then the sleeving will be stretched out to close the weave and ensure there's no visible wire underneath the sleeving. You want both ends of the sleeve to sit between the two flag pins on the terminals. To measure the sleeve to do this correctly, we put one of the ends of the sleeve in line with flag one.

8 SLEEVING LENGTH

[**Image G**] Once you have one end of the sleeving in between those two flags on one end of the wire, you need to then sort out the other end. Stretch the sleeving to the other terminal and the locator pins. This works incredibly well with shorter cables, but with longer ones it might be slightly too long, as the length gained through the expansion of the sleeving increases with the length of the cable when it's pulled tight. If it is too long, at this second end, instead of measuring to the locator pins, measure to the second flag (the one making contact with the bare wire).

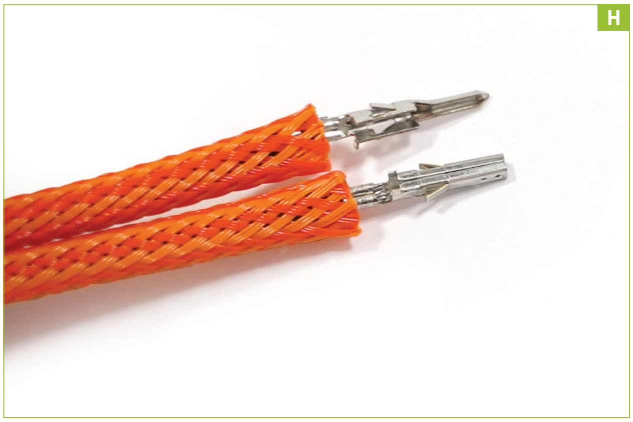


›› There's no exact science to this as each sleeve material has a different amount of tension, flex, and expansion rate, so this is something you will have to gauge as you are doing it, and as your level of skill increases. We always start with this method, though, as it's a great reference point.

9 CUT COMPLETE

[**Image H**] Once you have measured the sleeve and cut it, hit the end with a flame from your lighter to stop it fraying. If it starts to spread out, just pinch it slightly so that it stays the same diameter as the rest of the sleeve.

›› This next step depends on the material you're using to sleeve your cables. With PET sleeving, you can just push the terminal through. With paracord, however, you will need to use either a sleeving needle, some tape, or a cocktail straw, as mentioned last issue. When you have pushed the sleeve through, the sleeve should sit between both flags. If it is too long, trim the sleeve down and remember to use a lighter again to stop the ends from fraying. If it is too short, save the sleeving! It can be better to start with the longest sleeving runs and then do the shorter ones last, so you can use any sleeving you got wrong the first time for the next wires.

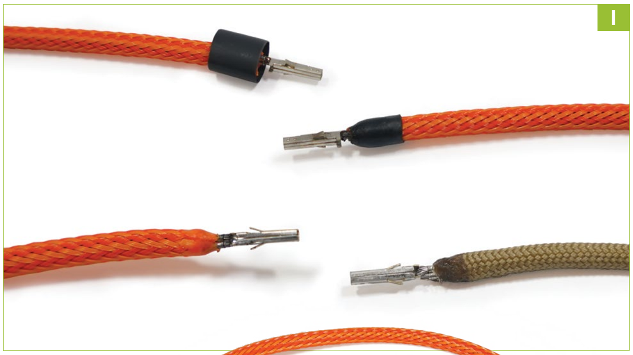


10 HEATSHRINK OR NOT?

[**Image I**] With PET sleeving you will need heatshrink to attach the sleeving to the wire. We use the MDPC-X heatshrink, which has been sourced for this specific application. To do this, cut around 3/8th of an inch of heatshrink off, and then put it over the sleeve, and wire so it is just covering everything. Again, make sure the sleeve is in between the two flags, then hit it with some heat via your lighter, and it will shrink.

›› The idea is that you are melting the sleeving inside the heatshrink enough that it will set around the pin. Once the plastic has melted enough, you will need to pinch it and use your fingers to make sure that the plastic is moulded nicely.

›› You want it to be a nice cone shape. Do be careful while doing this, as you will burn yourself—those who sleeve many power supplies often have no fingerprints left on their index fingers and thumbs! Once the sleeving has set a little, just cut off the heatshrink, leaving you with the completed wire. If you are using paracord, you don't need the heatshrink, as the weave doesn't unravel when you hit it with heat. You can just use the flame over it then give it a squeeze.



11 CABLE COMPLETE

[**Image J**] And that's it! That is a single wire sleeved, now you just have to push it into a connector and repeat the process for the other extensions you wish. We have just done a single wire for a six-pin PCIe cable here, so only another five to do and it is finished! The main thing while starting sleeving is that you give it a go, but ensure that you are being safe. Check everything multiple times, and if ever you think you have gone wrong, reach out to the sleeving community. ⏻

CONNECTORS & TERMINALS

There are many connectors and terminals you may encounter while sleeving. On the hardware side, you'll generally see six-pin, eight-pin or 12-pin GPU connectors (thanks Nvidia), four or eight-pin EPS connectors, and a 24-pin connector. At the PSU end, however, you can find almost any size of connector, from two to 24-pin. Due to this it is always a good idea to wait until you have your PSU before buying sleeving supplies. Also make sure that you visit a good sleeving-supply site to ensure that you get everything you need. As well as the standard connectors, you may want four-pin Molex, SATA, fan, and IO panel connectors and pins. These work slightly differently to ATX pins, but the principle is the same.

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Stream From a Birdbox With a Pi

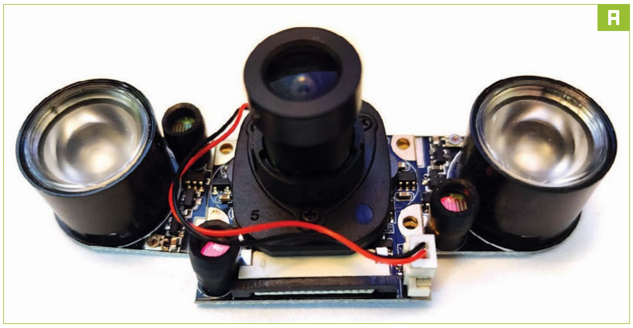
YOU'LL NEED THIS

A RASPBERRY PI & A COMPATIBLE IR CAMERA
Some wood and a few screws.
Friendly local bird life.

HELLO, AND WELCOME TO MAXIMUM CARPENTRY MAGAZINE, where "Minimum BS" stands for "Bowed Softwoods." This month, we'll be knocking up a bird-nesting box in about five minutes, then showing you how you can outfit it with clever camera trickery to watch the nestlings inside.

Oh, who are we kidding? We're better at routing cables than routing cabinets. However, we like birds, so we're going to take our mediocre woodworking skills and build that birdbox, then use a Raspberry Pi and an IR camera to outfit it with a night-vision surveillance system that can wirelessly (apart from power) send pictures directly to the internet for us to watch or share on a streaming site—in this case YouTube.

The pattern you use to build the box doesn't matter, but it's worth building your own (or buying an extra coffee for someone with the requisite skills), as ready-made ones rarely have the space for camera equipment. You'll also need to put a little more thought into waterproofing, and siting the box in a place where you can run a power cable to it. **–IAN EVENDEN**



1 CUT THE WOOD

Find a birdbox pattern online and buy a plank of wood of the correct dimensions from a hardware store. Follow the pattern, but add about four inches in height, and an extra "ceiling" to separate the Pi compartment at the top. You'll need to leave some space or cut a hole for the ribbon cable to pass through to the camera. We're using a Raspberry Pi 4 running stock Raspberry Pi OS and a camera with its own IR lights and photoresistor [**Image A**] to sense when to switch them on, although as it's likely to be dark in the box most of the time, we'll see a black and white night-vision picture. The brand name is MakerHawk, but you can find similar ones from other suppliers. If you want to let natural light into the box, consider cutting a circular hole in the side that will face closest to the sun, and covering it with PVC—this is essential if you want to see color.

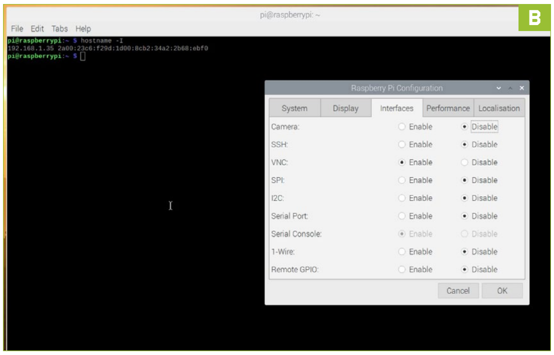
»You could use the official Raspberry Pi IR camera, but you'll need to add your own IR LEDs (check the particular needs of these IR lights—they need five volts and a resistor). If the Raspberry Pi kit you've got has active cooling, wire it up in quiet mode rather than full power—the birds will appreciate it.

2 FIX THE CAMERA

Fixing the camera in place on the bottom of the ceiling you've installed in the box can be one of the trickier parts. You can tape it, glue it, stick it with a lump of Sugru, or even fashion a metal plate to hold it in place with a screw. What you probably won't be able to do is screw it directly: The holes in the camera's PCB are small, and are also used to bolt the IR lamps on and supply them with power through contact connections. We couldn't easily find a screw that would go through without damaging the board but still provide enough purchase in the wood to ensure it wouldn't all fall down on a bird's head. We also found that the supplied ribbon cable was too short after it had twisted its way down to the underneath of the ceiling, so offer it up first to see if you need to purchase a longer one.

3 TEST THE SETUP

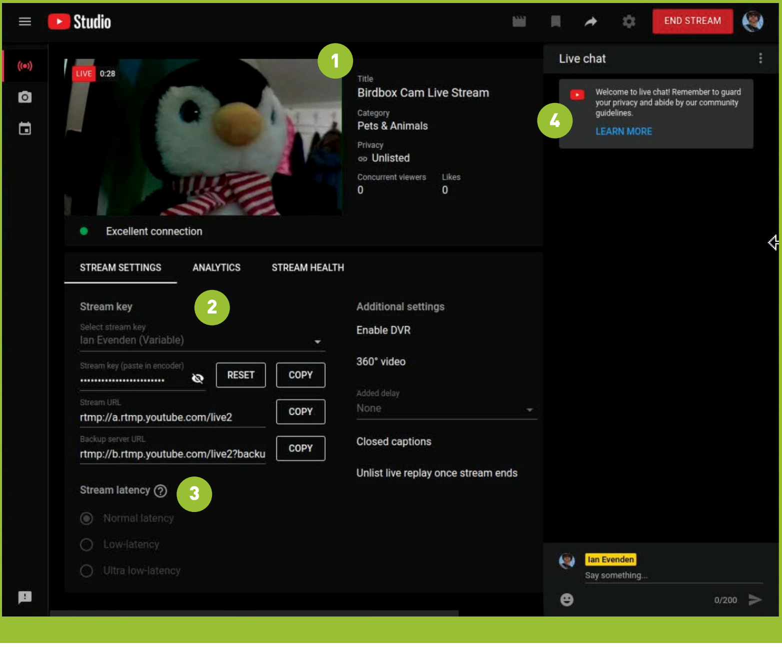
Put something in the box, and switch the whole thing on to test the focus of the camera. Ours, and many like it, has a manual focus-adjustment—the lens screws in and out. You'll need FFmpeg installed on the Pi, so open the terminal and type: `sudo apt install ffmpeg`. While we're at it, you'll need to set your Pi up for remote access. Once something feathery has taken up residence in your box, you won't be able to go in and make adjustments—disturbing nesting birds is a criminal offence in some countries, and is also not a nice move. Plus it's pretty hard to get a keyboard, mouse, and monitor working up a tree. We've tried. To gain remote access to the Pi, install the VNC Viewer app from www.realvnc.com/download/viewer on your PC. VNC server is ready-installed in Raspberry Pi OS, you just have to switch it on. Open the Raspberry Pi Config app from "Menu → Preferences → Raspberry Pi Configuration," and open the "Interfaces" tab. From here, switch VNC to "Yes" [**Image B**] and activate the camera from the same screen if you haven't already. Find your Pi's IP address



```
pi@raspberrypi:~ $ hostname -I
192.168.1.35 2a00:23c6:f29d:1d00:8cb2:34a2:2b68:ebf0
pi@raspberrypi:~ $ 
```

Camera: ○ Enable ● Disable
SSH: ○ Enable ● Disable
VNC: ● Enable ○ Disable
SPI: ○ Enable ● Disable
I2C: ○ Enable ● Disable
Serial Port: ○ Enable ● Disable
Serial Console: ● Enable ○ Disable
1-Wire: ○ Enable ● Disable
Remote GPIO: ○ Enable ● Disable

THE YOUTUBE STREAMING INTERFACE



Title
Birdbox Cam Live Stream
Category
Pets & Animals
Privacy
Unlisted
Concurrent viewers 0
Likes 0

Excellent connection

Stream key
Select stream key: Ian Evenden (Variable)
Stream key (paste in encoder): ••••••••••••••••••••••••
Stream URL: rtmp://a.rtmp.youtube.com/live2
Backup server URL: rtmp://b.rtmp.youtube.com/live2?backu

Stream latency
● Normal latency
○ Low-latency
○ Ultra low-latency

Additional settings
Enable DVR
360° video
Added delay: None
Closed captions
Unlist live replay once stream ends

Welcome to live chat! Remember to guard your privacy and abide by our community guidelines.

Ian Evenden
Say something...

1. PREVIEW
This is the preview window for your stream.

2. STREAM KEY
Keep this a secret, you'll need it for every stream you do.

3. LATENCY
Choose "Normal" for better quality, or Ultra-Low" for real-time interaction.

4. LIVE CHAT
The best of the internet, right up in your face.

("hostname -I" in the terminal), hop back to your PC, and type that IP address into VNC Viewer. You should now have remote access to the Pi from almost any device, including cellphones and tablets.

4

SET UP YOUTUBE

YouTube makes you jump through a couple of hoops before you can start streaming. Log in to the site, then drop down the menu under your avatar at the top right. Choose "Your Channel," then "Manage Videos." From here, click "Live," then "Get Started." You'll be asked to verify your account—the easiest way is with a security code sent by SMS to your cellphone number. Then wait 24 hours while your streaming account is activated.

5

START STREAMING

Once YouTube has given you the keys to your own account, you'll need to type one last command into the terminal in order to begin streaming. And it's a biggie.

```
raspivid -o - -t 0 -w 1920 -h 1080 -fps 30 -b 5000000 -g 50 |
ffmpeg -re -ar 44100 -ac 2 -acodec pcm_s16le -f s16le -ac 2 -i /
dev/zero -f h264 -i - -vcodec copy -acodec aac -ab 128k -g 50
-strict experimental -f flv <server>/<key>
```

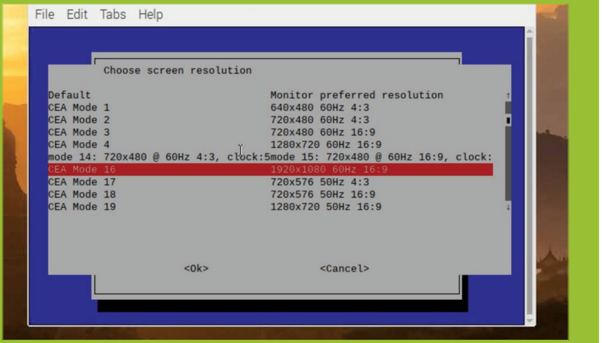
›› Replace <server>/<key> with the appropriate information taken from your stream's page on YouTube. What you're doing here is using Raspivid to send out a 1920x1080 stream at 30fps, with a bitrate of five megabits and a keyframe every 50 frames. It's done via the FFmpeg service you installed earlier, with a silent audio stream (YouTube needs audio, even if there's nothing there). The video is received from the camera in H.264 and sent to YouTube as FLV. On the webpage for your YouTube stream, you have further options, including whether the stream is saved for replaying later, whether it's public or needs a link to view it, the quality of your stream, and how many concurrent viewers you've attracted. There's also a live chat window. You can control the latency of the stream, so if you want to interact with viewers in almost real time, choose "Ultra-Low," but if you're happy for it to be a bit delayed and benefit from an increase in quality, choose "Normal." To stop the Pi from streaming, type Ctrl + C into the terminal window.

6

WATCH THE BIRDS

With this all working, there's nothing left to do but wait until the first signs of spring, when we can stick the box up in a tree (with a very long USB-C cable run from an outbuilding to supply power), and see what we get. ⏻

HEADLESS PI



```
Choose screen resolution

Default                                 Monitor preferred resolution
CEA Mode 1                              640x480 60Hz 4:3
CEA Mode 2                              720x480 60Hz 4:3
CEA Mode 3                              720x480 60Hz 16:9
CEA Mode 4                              1280x720 60Hz 16:9
mode 14: 720x480 @ 60Hz 4:3, clock:5mode 15: 720x480 @ 60Hz 16:9, clock:
CEA Mode 16                             1920x1080 60Hz 16:9
CEA Mode 17                             720x576 50Hz 4:3
CEA Mode 18                             720x576 50Hz 16:9
CEA Mode 19                             1280x720 50Hz 16:9

                <Ok>                        <Cancel>
```

Running a Pi with no monitor attached can sometimes throw up an error in VNC Viewer, where the app claims it can't display the desktop. This happens because, by default, the Pi sources its output resolution from the monitor as it starts, and gets confused if there isn't one there. The problem can be fixed by opening the config utility (`sudo raspi-config` in the terminal) and setting a fixed screen resolution (say 1080p at 60Hz). If you do this, remember to turn off pixel doubling in the same app, or you'll get a very large interface that's cumbersome to use. While you're in config, check that the Pi is set to log into desktop mode on startup—this makes it much easier to use if you're not a wizard at the command line.

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How To Apply Thermal Paste

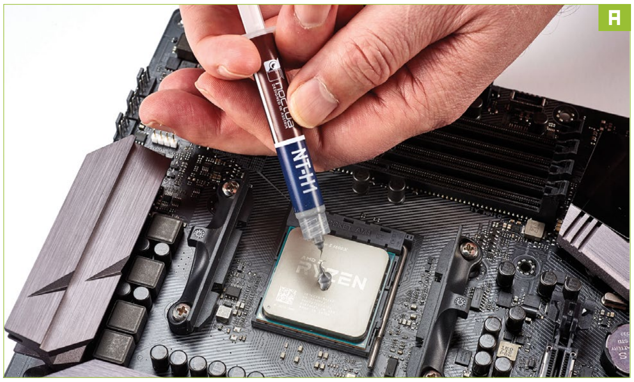
YOU'LL NEED THIS

NON CONDUCTIVE THERMAL PASTE
Recommended, Noctua NT-H1.

EVERYTHING IN COMPUTING IS POLARIZED. Nvidia or AMD? Apple or Windows? PC gaming or console? There's a whole plethora of argument-inducing debates to be had and statements and brands to align yourself with. And that is very frustrating, because a lot of the time it genuinely gets in the way of real progress and learning. Nowhere is this more evident in computing than with the "debate" surrounding the application of thermal paste.

When you take a step back and think about it, it sounds insane. How can arguments descend out of this madness? Surely the way someone applies thermal paste isn't worth having a fight over? This journalist has to admit he didn't always think like that. There was one way of applying thermal paste, and that was it. It was only after being challenged by our resident modder and peripheral guru, Dave Alcock, that he finally did a bit of testing, and changed his ways.

Simply put, how you apply thermal paste has no noticeable effect on temperatures at all, as long as there's enough paste between your CPU's integrated heat spreader and the CPU block attached to your choice of cooler. That's it. It doesn't matter. You can empty an entire tube of the stuff onto a processor if you like, the reality is there's no noticeable temperature difference outside of margin of error at all between a carefully applied layer and a tube of the stuff thrown on top. But that said, if you want to save some cash and maximize your thermal paste (saving some for later, and reapplications), or alternatively you're looking at applying a liquid-cooling block to a GPU, where do you begin? **–ZAK STOREY**



1

THE RIGHT PASTE

Perhaps more important than anything else when it comes to thermal paste is that you choose a paste that's easy to spread and non-conductive. You don't want a runny paste that spills out everywhere, and nor do you want one that has some form of conductive capacity to it.

» If you accidentally spill some of that on the side or onto the processor's PCB, you're looking at a short circuit, a quick trip to RMA land, and one expensive bill in the process. That's not to say there isn't a place for this stuff (it's great on older processors that you can delid carefully), just that for everyday use, you're better off with the non-conductive stuff.

» We always use Noctua NT-H1 at *Maximum PC* [**Image A**], not because we have some advertizing deal with them, but purely because its consistency is thick, meaning you can apply it pretty much upside down if you wanted and it'll sit in place, perfectly fine. It also takes an eternity to dry out, and provides strong performance, with zero conductivity too—all trademarks of a good paste. The H2 stuff, although just as good a performer, is a bit worse in our eyes, because it's more liquid than solid, and not as confidence-inducing as the H1 line.

2

THREADRIPPER AND BEYOND

With any mainstream Ryzen processor or Intel LGA 1200 chip and below, you can get away with just taking a tube of paste and applying anywhere between a pea-sized dot (or a grain of rice, or whatever your desired size metaphor is) and a small pebble in the middle of your processor and be absolutely fine, as long as it's non-conductive.

» That said, there are processors around on which this won't work as effectively—Threadripper being one of them. In this instance, we typically apply two thick lines, inwards down the longest sides of the chip, with a bigger dot in the middle. By design, the core complexes on Threadripper sit in a cluster of four, one in each quarter, so making sure you have ample coverage here is important. The same goes for Intel's high-end Xeon parts—ensuring you've got plenty of thermal paste coverage here is paramount to solid thermal performance under load.

3

GPUS AND WATERBLOCKS

When it comes to graphics cards, you'll often see manufacturers such as EKWB, Phanteks, or Alphacool recommend that you create a star pattern of thermal paste on the GPU itself, with their included paste. You really don't need to do this at all. The GPUs themselves are still relatively small compared to the likes of the high-end desktop chips, and as such you can get away with approaching it in a similar manner to Ryzen processors and LGA1200 and below parts. A big dollop in the middle and you're good to go.

» If you're still not quite convinced that thermal paste application doesn't matter, you can check out this video here from our friends over at *Gamers Nexus*, where they go into far more detail regarding testing the whole procedure: http://bit.ly/TPasteNexus.

BUILD IT

ZAK STOREY, EDITOR

Case Transplants

It's time to transfer our build from the Hydra Mini to Razer's new Tomahawk

LENGTH OF TIME: **2-3 HOURS**

LEVEL OF DIFFICULTY: **FRUSTRATING**

THE CONCEPT

IF YOU HAVEN'T read our review of the Tomahawk ITX chassis just yet, you're in for one hell of a treat. This thing is a seriously slick box. For its first consumer case (or one of two, I should say), Razer has really managed to hit the nail on the head. The design elements are there, the lighting is sophisticated and sleek, and the quality-of-life stuff is included too. For an ITX case (which have always been a notorious pain in the butt to deal with) it's pretty damn good.

It's not flawless—there's some minor missteps here and there that need addressing in iteration 2.0—but they're just small frustrations rather than larger oversights, and things that you can work around easily enough. Needless to say, if you like Razer's products, and you're after an ITX chassis, you're going to love this.

So, the concept for this build, what is it? Well, this is actually going to be a transplant build. There's no better way of testing and reviewing a chassis than living with it day to day. To give you a little insight into how we do things here at *Maximum PC*, we have two rigs that we use on a daily basis "in the office" (read: "home working"). One is a Windows machine, where we do the majority of our testing, gaming, benchmarking, and writing. The other is a company-issued MacBook, where we manage our content on the internal servers, and use our bespoke pagination software to make sure everyone on the team knows what state each page of the mag is in. That being the case, typically we have a Windows machine at work, one at home (a personal machine), and then the corporate MacBook that we can transport between the two locations.

Now that we're remote working on a semi-permanent basis, the home and work machine have blended together, and as such in my case, I have one Windows machine—that sweet, sweet Hydra build from a few issues back—and my MacBook. Transplanting that Hydra build into this case is nothing if not a risk: If something goes wrong during the transplant, I've got to work my butt off, out of hours, to get the thing back running again, otherwise I'm left without a rig for either personal or office use.

ZOTAC GAMING

SO ANY PART SWAPS THEN?

SADLY, this time around, no. This is going to be a little bit of an underwhelming build in terms of performance figures, as technically we've pretty much already seen them. On the whole, not a lot is changing between this and the Hydra build I did a few issues back. Since I first got the Hydra rig home, and ended up using it as my work and gaming machine, I have made one slight change to it, and that's swapping out the paltry 16GB of Corsair Dominator Platinum RGB DDR4, for a 64GB kit of HyperX Predator DDR4 instead, which you might recognize from our tiny but powerful ITX PC inside the NZXT H1. The reason for this is that I really wanted to see if *Star Citizen* performed better with more memory. It sort of does.

Outside of that, the second change I'm making is the move over to an EKWB 240mm AIO instead of that Noctua cooler on the Hydra. That's not because the Noctua NH-L9i isn't sufficient at cooling the processor—far from it—but more because... Well... I kinda miss RGB lighting. Although that will bite me in the butt at a later moment. You'll see.

Why no GPU swap? Well, we do have access to the 3000 series of GPUs now, and AMD's promised us some Radeon samples in the next few issues, but sadly, none were available at the time of the build, so I'm sticking with my replica Sun (seriously, it's so bright), Zotac's RTX 2080 Super AMP Extreme.

INGREDIENTS

PART		STREET PRICE
Case	Razer Tomahawk ITX	$180
Motherboard	Asus ROG Strix Z490-I Gaming	$293
CPU	Intel Core i5-10600K	$263
GPU	ZOTAC GeForce RTX 2080 Super AMP Extreme	$780
Memory	64GB (2x32GB) HyperX Predator DDR4 @ 3600 C18	$318
PSU	750W Corsair SF750W 80+ Platinum	$185
Storage	2TB Samsung 970 Evo Plus	$350
CPU Cooler	EK-AIO D-RGB 240mm	$120
OS	Windows 10 Home 64-bit OEM	$24
Total		$2,513

1

USED HYDRA

SO HERE'S THE BUILD we're disassembling and placing inside the Tomahawk ITX. It's a beautiful thing, genuinely one of my favorite cases of all time. Practical? Absolutely not. And a bit of a pain in the butt to keep tidy too (can you see all the fingerprints?). I absolutely fell in love with it over the last few months: The small form factor, its looks, the good performance, the GPU that acts as backlighting—it's going to be missed. As you can probably tell I never did get around to going into the office to pick up the Silverstone SFX power supply with custom short cables, but honestly I quite like the stealth look.

2

RAZER STRIPDOWN

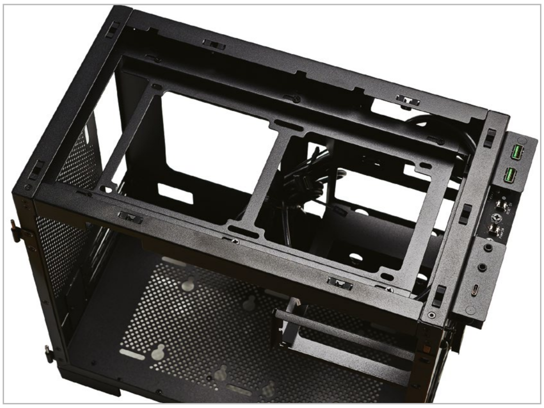
HERE YOU HAVE IT, the Razer Tomahawk ITX with its side panels off. Both panels are smoked tempered glass, sat on removable hinges, and secured down via magnets located on the front edge of the case. In front of that you've got a solid front panel with filtered air intakes along the sides running around two-thirds of an inch deep, and a cutout in the bottom for better airflow. It looks clean, although that green logo sat in the front of it is a bit of a concern. In the era of RGB lighting and customization, we really shouldn't be seeing these things anymore.

3

ROOF MOUNTS

TO REMOVE THE FRONT PANEL simply pull it away from the case, from the bottom, using your fingers. From there you can remove the top panel in a similar manner. Both panels sit in push-pin sockets, and the pins are metal too, so there's no risk of breaking or accidentally snapping them off at any point.

The top panel has small square perforations running down the length of the radiator mounting location to allow for decent airflow, and there's no dust filter meshing here either, which is a plus for airflow. You can also see that we've got extensive front I/O, and a removable 240mm radiator bracket too.

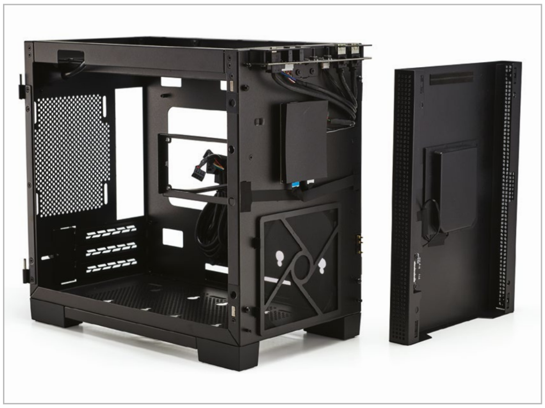


4

FAN FILTERS & LIGHTING

WITH THE FRONT PANEL OFF you can see the panel design behind it. As far as I can tell the big block in the center of the case is an RGB control board that you don't get access to, and then that massive block in the center of the front pane is the lighting for the Razer logo. At first glance it does seem a bit like overkill, but boy does it light up well after it's built, so we'll let it slide this time. The panel connects via metal contact pins, so no pesky cables to unplug or anything like that during maintenance.

There's also a small removable fan filter for a 120mm intake fan, for those times when you don't have a fat graphics card like this in this build.

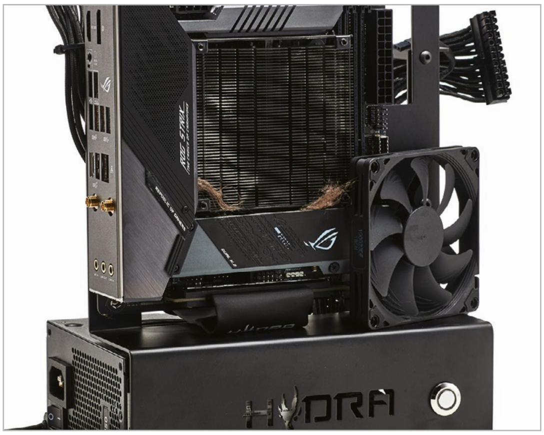


7

GENUINELY GROSS

CAN YOU TELL I own a chocolate labrador? OK, I have an admission to make here, I like to pop my feet up on the desk when I'm working—it's just more comfortable for me, and probably better for my posture, maybe. When a PC is exposed in an external case like the Hydra Mini, it does mean it can pick up a lot of crud in that intake fan, in particular dog hair and dust from my socks.

Three months later, and a surprising amount of blasting with cans of air, and this is the result: A slightly grim-looking build-up of dog fluff on the bottom edge of the cooler.

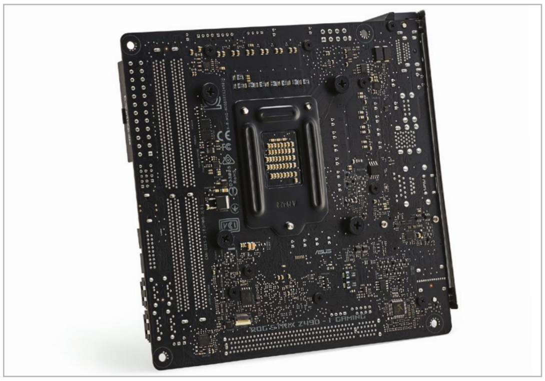


8

CLEVER DESIGN

I KNOW I WENT ON about this last issue, but seriously, the Noctua NH-L9i is a true marvel of engineering. Or at least, it breaks the norms, and for a tiny heatsink, it really does kick butt. How do you install it? Via these four fan screws on the back. Apply your paste, position the cooler, install the screws from the rear, job done. It's just a genuinely clever design.

To remove it, simply do the reverse. Undo the screws, take the cooler off, clean up the paste, done. One thing I technically don't need to do is remove the low-profile fan that comes with it. But because I've messed around with the cable to tuck it out of the way between the memory and the CPU socket, it's a good idea.



5

OLD BUILD DISASSEMBLY

WHAT YOU'RE SEEING HERE is me making a mistake, namely beginning the disassembly process without removing the cables first. That wouldn't normally be much of a problem, but a single Allen-head screw holds this graphics card into its bracket, and once that's undone it immediately falls out, and down. Remember that the Hydra Mini doesn't actually have anything for the GPU to sit on outside of its small bracket, so it is nerve-wracking to say the least.

6

GPU OUT

WITH THE GRAPHICS CARD OUT (being careful with the PCIe power cables and the riser cable), it's time to yank the memory out too (not literally). Then it's a case of removing the cooler, and that's about it. At this point I can leave the processor and the M.2 storage installed.

Intel has an edge over AMD is when it comes to swapping out coolers. The suction created via thermal paste on an AMD chip and its heatsink during the removal process can rip the chip out of its PGA socket, leading to a lot of thermal paste everywhere, and you having to carefully twist the chip off the base of the cooler. It's just not quite as secure as Intel's sadly.

9

MORE POWER?

AND HERE WE HAVE IT, one disassembled system, ready to go into the new chassis. I'm still using the Core i5-10600K here. Theoretically I could've gone for the Core i9-10900K to give myself those extra cores, but honestly, for what I do on a day-to-day basis, it's totally not needed. I can't believe I'm saying this after all these years of benchmarking flagship chips, but really, this is enough.

One thing I do want to complain about, however, is the tiny "republic of gamers" sticker on the bottom-left side of the board. In short, it just decided to peel off one day, and I was forced to use a tiny amount of glue to stick it back on, which went well...

10

A TOUCH TIGHT

ON TO THE TOMAHAWK ITX. After pre-installing the EK backplate onto the board, popping the GPU in is a problem. Because it's longer than most GPUs, it shouldn't fit. To get around this, I've removed the front fan filter, moved the tip of the GPU out of the opening, then back into position into its PCIe slot. With the limited cable-routing options, and lack of space to work in, this thing has had to go in and out of the case four times before everything is correctly in position. For instance, the USB header and D-RGB headers are located ever so slightly above the PCIe slot.

The one downside to the long card is that it stops me from installing a 120mm front fan. That means I'm going to be running a negative-pressure system.

11

POWER SUPPLY WOES #1

THERE'S A FLOATING SFF PSU mount in the top right, with a passthrough cable that runs along the top of the case. You can install the PSU so the fan is facing in either direction, but, I've opted to install with the fan down and the cable connector on the right, at the front of the chassis.

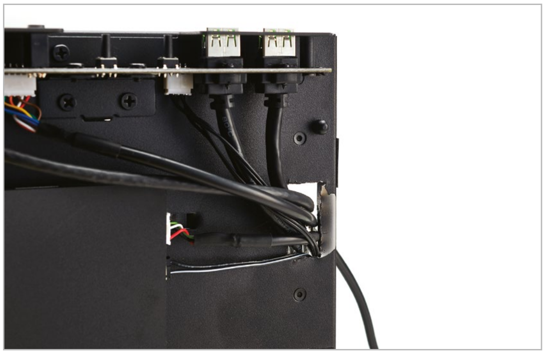
The problem is, the passthrough cable hangs down through the middle of the chassis. If you install the power supply with the fan facing up and the connector to the left, then plug the passthrough cable in, it looks odd. Flip it and the passthrough cable won't reach the connector at all. But there's a work-around. Props to Razer for the small pilot holes for the screwdriver. The included PSU screws don't fit through, so thread them in the gap in between first, then thread the screwdriver through to secure them.

12

POWER SUPPLY WOES #2

ME BEING ME, I decided I could "mod" this into submission. On the front panel there's a rectangular cutout to allow all of the front I/O cables through. In my head I could thread the passthrough cable through there, round the front, and back in again (oblivious to the fact there isn't another passthrough on that side). Problem is the kettle-lead connector head is slightly larger than the steel cutout, so it won't fit, no matter what you do.

Despite hammering, filing, and bending, it's no good. However, I can just unclip the cable, run it through one of the upper cable passthrough holes for the PSU cables, and plug it directly in to the right of the power supply, keeping it nice and tucked out of the way. In future Razer, run the PSU passthrough out of the way, and keep it tidy.



13

CABLE HELL

SO! POWER SUPPLY IS IN, motherboard and graphics card are secure. Everything's plugged in. What's the problem? Well the rear door won't shut. There's just too much cable bulge. Now I appreciate this is a very niche problem, likely created by the fact I'm not using standard SFF power supply cables in the build, but no amount of smart cable-management allows me to close this door.

After getting it home, I've managed to cable-strap things down, but even the most gentle of nudges cause the rear window to pop open. Given the nature of what you can actually see back here, having a glass window on hinges doesn't make sense. Either have it securable via a thumb-screw, or replace it with a steel panel. It will give more versatility for cable choice, and stability.

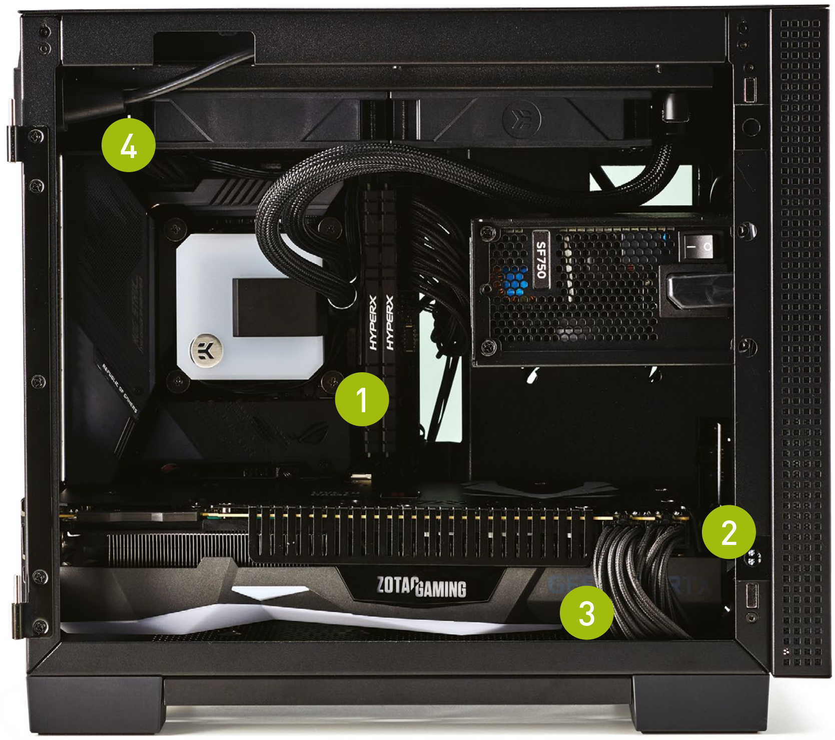
14

CPU BLOCKS AND NIGHTMARES

A PAIN IN THE BUTT is that some CPU blocks are too big for the Z490 ROG Strix-I Gaming. The bracket on the CPU block makes contact with that raised PCB for the soundcard and M.2 slot. If you place it down, you'll scratch the PCB, it won't sit right on the chip, and if you do secure it, you'll see sky-high temps. To get around that, tuck the bracket under the add-on PCB as you place the block down.

The next problem is the ports for the tubing to the radiator. If they face up they contact the VRMs; face to the left, they hit the rear I/O shield; face down, they hit the raised PCB; face right, they're too close to the DIMMs. The painful solution that I wouldn't recommend long term is to install the memory first, then install the CPU block, putting sideways pressure onto the DIMMs. This moves them off to the side, gives you anxiety, but does function.

SF750
HYPERX
HYPERX



1 The memory bending next to the CPU is seriously concerning, and not a long-term solution, especially if you intend to transport it anywhere.

2 You can just about see the magnets in the front of this chassis here. There's another set of these on the other side of the case where the cable management is, and they need to be much stronger

3 The best way of running the PCIe power cables is actually underneath the GPU itself. Don't worry, there's ventilation in the floor to give it good access to cool air.

4 All the fan cables located at the top of the motherboard here are difficult to plug in. Keep the radiator bracket unsecured until you've installed them all, so you can move it around.

FRUSTRATING BRILLIANCE?

FIRST OFF, building in the Tomahawk is a very nice experience. I can't stress enough that for its first consumer-facing case that isn't just a concept prototype with gullwing doors, it is a fantastic choice for anyone looking to build a small-ish form factor system.

It reminds me a lot of the original BitFenix Prodigy, when that first launched back in 2012—not in design, but in ambition. It does need some work—that rear panel needs some dressing up, and it really needs an extra intake fan slot too, as well as being a bit longer forward, and have a deeper recessed cable-management area as well. And that cable passthrough for power, please do something about that. But otherwise it's a solid effort, and we're happy with the result.

The biggest gripe I had was actually with the cooler and the motherboard itself. It's just frustrating the EK block doesn't fit well in this combo, which is disappointing to say the least, because it is an absolutely stunning piece of design, and the way that light diffuses out of it is exceptionally good looking.

As for day-to-day life, it's nice having a case again, in a lot of ways: The GPU is a bit quieter, muffled by all that metal and glass, and the extra lighting and design elements do look good in my office. But that is another point of contention. Seriously, considering we've had RGB elements in products now for well over five years, it feels bizarre that we're at this point where the software behind it still functions as well as a bag of bricks does at being a house. It genuinely bothers me that Razer, SteelSeries and Corsair seem to be the only ones who've got their act together when it comes to configuring RGB software, and they design peripherals and cases first, not motherboards, graphics cards, and BIOSes. Trying to use Asus's Aura Sync or Creator or whatever it's called this month is a nightmare: It rarely works, it doesn't detect anything, it looks like something from 2006. Even the lighting's not as bright as it would be if I just used it with the Corsair iCUE plugin. We need a unified, good-quality platform to control RGB. The same goes for Gigabyte, MSI, and ASRock. If RGB is the future (which let's face it, it is), this needs to be addressed.

As for performance? Well it's exactly what you'd expect, sadly our benchmarks don't really showcase any improvements in regards to memory capacity, and the frequency is identical as well. The only downside is a slightly slower CAS latency rating, but all in all, it's a well balanced system ready for the next decade. Heck, who knows. maybe it doesn't need a GPU update until Nvidia's 4000 series or AMD's 7000 series .

Ultimately this little Tomahawk build is pretty kick-ass. It looks good, performs well, is now far quieter than it was before, and the slight improvements to memory capacity and cooling have improved my work process.

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	1,350	1,421 (5%)
CrystalDisk QD32 Sequential Read (MB/s)	3,536	3,534 (0%)
CrystalDisk QD32 Sequential Write (MB/s)	3,196	3,170 (0%)
Middle Earth: Shadow of War (fps)	55	55 (0%)
Total War: Warhammer II (fps)	47	47 (0%)
Assassins Creed Odyssey (fps)	36	36 (0%)
3DMark: Fire Strike (Index)	22,306	22,652 (2%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an Intel Core i5-10600K, 16GB of DDR4 @ 3600, a Zotac GeForce RTX 2080 Super AMP Extreme, and a 2TB Samsung 970 Evo Plus M.2 PCIe 3.0 SSD. All tests were performed at 4K with the highest graphical profile.

LAB NOTES

TESTED. REVIEWED. VERDICTIZED.

I Live, I Die, I Live Again

What is it about roguelikes that keeps me coming back?

AS A RULE of thumb, I hate dying in video games. Death is failure. I've dipped my toes into From Software's titles a few times, even slogging through the miserable entirety of *Dark Souls 2*, but every "YOU DIED" felt like a dagger piercing my soul. As a youngster, I spent hours tirelessly grinding in *Pokémon Crystal* so my team would be suitably overpowered to prevent the black screen of defeat.

Why is it, then, that 2020 has me suckered into a whole bunch of games where dying over and over again is part of the deal? Roguelikes have taken a hold on my heart, to the point where I actively anticipate each death with a mixture of curiosity and excitement.

The genre has expanded and evolved a lot over the years. The best roguelikes use the endless loop of dying and returning as a tool for the player to further the story or uncover more of the world, and few have reached the excellence achieved by the weird and wonderful *Hades*. Here, death is a mere stumbling block; you slip sullenly from a pool of blood in your godly father's house, ready to socialize with its residents and take another shot at escaping the underworld.

I swear, it isn't just Dionysus's chiseled abs that keep me coming back.

Hades feels special because of its pitch-perfect character design and overarching plot, which slowly unfolds over the course of dozens of failed escape attempts.

It's not the only roguelike to grab me this year, though. *Risk of Rain 2* is an absolute blast with friends, providing a type of chaos that makes dying feel like it's never your fault. Away from shooting and slashing, *Monster Train* does a great job of scratching the itch for card-based roguelikes that *Slay the Spire* left me with.

I can't quite explain it. In any other game, dying fills me with disappointment, but in roguelikes, I almost relish each defeat. Perhaps it's the tantalizing, inch-by-inch progress each run makes towards the endgame; maybe it's the way these games train me to master their intricate systems through punishing death after punishing death. Either way, I'm hooked. **–CG**

INDUSTRY INSIDER

As I write this, AMD has finally taken the crown from Intel in its single-core IPC race to the top. It may have taken three generations of architecture, and an impressive die shrink down to what it is calling 7nm, but the plucky underdog has come from behind and given its historic competitor a good kicking with its latest Ryzen 5000-series processors. That last bastion of Intel's is now gone. So what's next for the big blue company?

There's no denying that the Skylake architecture was a fantastic step in the right direction for Intel, so iterating on that was a solid strategy, but that was back in 2016, and dithering around trying to get 10nm functional just hasn't been worth it in the long run. I get it, lithographs are seriously expensive, so getting every last cent out of that old one was important, but is it worth losing that performance crown? Losing that market share? It feels like a mistake.

And now we hear that its own 7nm process will be delayed until potentially early 2023. That's an astronomical time gap. We know you're capable of the design work Intel, we know you've got the money, and if it means you have to go to a third party to grab that sultry 7nm process, then by all that's good, you need to do it. Capitalism thrives on competition, and competition defines progress—without it we may very well see a triumphant AMD rest on its laurels and the industry stagnate once again.

© GETTY IMAGES

Editors' Picks:
Corsair HS60 Haptic

This headset comes with haptic feedback that can vibrate you to your eyeballs—but that you can also switch off

THIS IS the Corsair HS60 Haptic gaming headset. The HS series of headsets are generally a bit more toned down than a lot of Corsair's products: There's no RGB or anything too crazy, just an emphasis on build quality, comfort, and audio performance. And it's done well.

In fact, the original HS60s were some of the best budget(ish) headsets out there when they first launched in 2018. However, something else happened that year, and that was the launch of Razer's Nari Ultimate gaming headset, complete with haptic-feedback drivers. I was fortunate enough to take a look at these back when they first launched, and they were an interesting concept, with some significant flaws. Mainly this revolved around the lack of an off switch, and the biggest problem was that they were $200. That's a hefty investment for a headset developed around a design concept that you couldn't actually disable if you didn't like it.

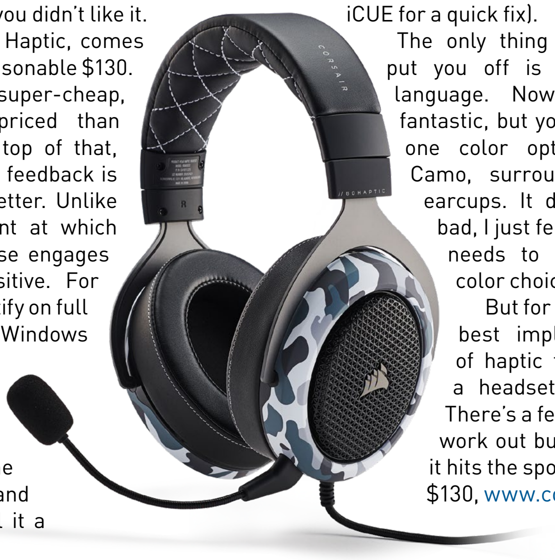
Corsair's HS60 Haptic, comes in at a far more reasonable $130. Now it's still not super-cheap, but it's better priced than Razer's Nari. On top of that, the way the haptic feedback is implemented is better. Unlike the Nari, the point at which the haptic response engages is far more sensitive. For instance, with Spotify on full whack, and the Windows volume set to around 12-14, there's no feeling of haptic feedback at all. Crank the volume up to 20+ and you'll start to feel it a little bit (with some variance, depending on the audio you're listening to). Push it all the way up to 40+ and it'll vibrate your cranium thoroughly. If you just want to relax, you can; if you want to game in an intensive subwoofer environment, you can do that too. However, best of all, it actually has a dial on the right earcup where you can control the amount of haptic feedback it produces. So if you want to turn it off, you can, and if you want to reduce the amount of vibration, while still increasing the volume, you can do that too. So even if you don't like it, you still have a solid headset.

Personally, I find the haptic feedback odd; at the higher intensities it feels like it's vibrating my eyeballs, and it tickles me somewhat too. Vibrations aside, audio quality is impressive, especially at this price. It's not mind-blowing—there's clearly been some clarity loss due to the unique design of these drivers compared to the original HS60—but it's nothing you can't fix with a bit of EQ tweaking (I recommend the "Clear Chat" profile in iCUE for a quick fix).

The only thing that might put you off is the design language. Now, it looks fantastic, but you only have one color option: Arctic Camo, surrounding both earcups. It doesn't look bad, I just feel like there needs to be another color choice.

But for $130 it's the best implementation of haptic feedback in a headset I've seen. There's a few niggles to work out but otherwise it hits the spot. **–ZS**

$130, www.corsair.com



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Nvidia GeForce RTX 3090 Founders Edition

Heir to the Titan throne

FOR YEARS, the Titans have reigned as the kings of the graphics world—mighty GPUs that are more of a show of force than anything regular mortals should purchase. The first of the Titans rose from the primordial dust so long ago that most of us can barely remember it. 2013 seems but a fond memory now. After seven descendants, however, the Titans have finally been dethroned. RTX 3090 has kicked their collective butts into Tartarus and staked a claim as the ultimate gaming GPU for the rising generation. It's generally much faster than the Titan RTX and costs $1,000 less. What's not to love?

In hand, one thing that's impossible to overstate is the massive heft of the RTX 3090 Founders Edition. We've looked at a lot of large graphics cards over the years, including Zotac's AMP Extreme line. The RTX 3090 FE dwarfs them all. It tips the scales at nearly 4.8 pounds. This writer tweaked his wrist doing yard-work while working on the 3090 review, and picking up the card would bring a wince of pain in surprise every time. Thank goodness the cooler and backplate are well-built so that the card won't sag at the back once it's installed in the typical ATX tower. Plus, if you hear noises in the dark at night, it can also stand in as a club. (Don't forget to power off your PC before removing the club/card—we're sure the bumps in the night will wait.)

Truly, though, this is a weapon fit for the gods, capable of vanquishing even the most demanding of foes. And by foes, we mean games. Across our test suite, the 3090 averaged 109fps at 4K ultra, even keeping minimums above 60fps—though that isn't to say every game will be a breeze. *Bright Memory Infinite* has a bunch of ray-traced effects that will punish even the 3090—it barely cleared 60fps, and minimums were in the mid-40s, and that's with DLSS Performance mode (4X upscaling) enabled.

Still, this is the fastest GPU around, and is likely to be for the next year at least. It's also the only 30-series GPU with SLI/NVLink support, though Nvidia has basically abandoned SLI support in gaming anyway, so unless you're doing GPU-compute workloads, we wouldn't worry about buying a second card.

There are a few thunderclouds, unfortunately. With a starting price of $1,499, the 3090 is more than double the cost of the 3080. It's also only about 13 percent faster in games, and that's at 4K ultra—the gap shrinks to less than 10 percent at 1440p or 1080p. If ever there was a card built for high-resolution gaming, it's the 3090. Nvidia is even billing it as an 8K gaming GPU! (That's mostly with DLSS Ultra Performance mode 9X upscaling.)

It's also important to point out that the 3090 doesn't have certain professional-level features switched on in the drivers. We tested SPECviewperf 13, and while the 3090 does well in four of the tests, it's slower than the Titan RTX in the remaining five. SolidWorks, CATIA, and Siemens NX all favor the Titan RTX—the latter being 20 times faster. It's no big loss for gaming purposes, but if you're more of a prosumer looking to straddle the line between GeForce and Quadro, there's no true Titan Ampere GPU this generation. At least, not yet.

Other professional workloads are a different matter. Blender, Octane Renderer, and Vray performance are 50 to 130 percent faster on the 3090 vs. the Titan RTX. Deep-learning and AI-type computations are also potentially more than twice as fast, thanks to Ampere's support for sparsity (see last month's Ampere architecture deep dive).

But by far the biggest problem with the RTX 3090 is going to be finding one in stock. More than a month after the official launch, the 3080 and 3090 remain sold out. Nvidia's CEO even said that shortages are expected to continue into 2021. If you can find and afford the RTX 3090, count yourself lucky. Otherwise, it's the usual story for godlike whims: Nvidia giveth, and Nvidia taketh away. **–JARRED WALTON**

VERDICT

8

Nvidia GeForce RTX 3090 FE

+ **ZEUS** Fastest GPU; enhanced architecture; beefy cooling; 24GB VRAM.

− **HADES** Power hungry; limited launch supply; lacks Titan features.

$1,500, www.nvidia.com

BENCHMARKS

	Nvidia GeForce RTX 3090 FE	Nvidia GeForce RTX 3080 FE
Borderlands 3 (Min/Avg fps)	**66/76**	58/67
Tom Clancy's The Division 2 (Min/Avg fps)	**70/82**	63/74
Far Cry 5 (Min/Avg fps)	**90/108**	82/97
Final Fantasy XIV (Min/Avg fps)	**65/124**	55/108
Red Dead Redemption 2 (Min/Avg fps)	**68/83**	63/75
Shadow of the Tomb Raider (Min/Avg fps)	**77/95**	69/84
Strange Brigade (Min/Avg fps)	**154/181**	133/156

All testing conducted with Core i9-9900K, MSI MEG Z390 ACE, 2x16GB DDR4-3200 CL16, 2TB XPG 8200 Pro M.2 SSD, Seasonic Focus G 850W. Scores are at 4K ultra and show 'minimum' 99th percentile frametime fps and average fps. Best scores are in bold.

SPECIFICATIONS

GPU / Architecture	GA102 / Ampere
Lithography	Samsung 8N
Core / Boost Clock	1.4 GHz / 1.7 GHz
Memory	24GB GDDR6X
GPU Cores	10,496
Single Precision	35.68 TFLOPs
TDP	350W
Display Connectors	HDMI 2.1, DisplayPort 1.4a

The RTX 3090 is the largest graphics card Nvidia has ever created, with a massive triple-slot cooler.

The anti-glare screen functions well even in a sunny outdoor environment.

HP EliteBook 845 G7

AMD teams up with HP for a sweet new laptop

HP'S POWERFUL notebook computers have been kicking around for a while, but the arrival of Ryzen 4000 has meant that new models needed to hit the home offices. We've got our hands on the EliteBook 845 G7, which packs a fierce octa-core Ryzen 7 PRO 4750U processor. Pricing varies significantly with this laptop, as there are numerous SKUs.

That's the most powerful chip AMD has to offer in the professional Ryzen range, promising up to 21 percent better average performance compared to the non-pro 4700U you'll see in more conventional laptops. Performance against Intel chips is a bit less clear, although AMD insists that the 4750U should comfortably beat the similarly powerful i7-10710U in both multi-threaded and graphical tests.

Speaking of graphics, this EliteBook uses Radeon Vega integrated graphics that have a surprising amount of oomph for a compact notebook. In practice, the 4750U blew our zero-point notebook out of the water, dominating multi-core benchmarks and managing to scrape by in 1080p gaming with settings at low to medium. No, you won't be playing *Cyberpunk 2077* on this, but it can handle a few rounds of *Fortnite* or 2D indie titles.

The standard 16GB of memory sits in two accessible slots so it can be upgraded by the user, up to 32GB of DDR4-3200. Storage is not upgradable, handled by a single M.2 SSD. Our review unit only has 256GB of storage, which will be plenty for anyone only looking to use this laptop for word processing and slideshows, but the storage options go up to 1TB for anyone who needs to store 4K footage or gigantic datasets. Regardless of capacity, it's seriously fast, hitting the same file-transfer speeds you'd expect from any 3rd-generation desktop M.2 drive.

In terms of physical design, this is obviously a premium notebook. The clean silver-and-white design oozes professionalism, from the fingerprint scanner to the soft white keyboard backlighting. The keyboard uses rubber-domed membrane keys for quiet typing, but retains a good amount of resistance on each keypress. A trackpad with integrated buttons is joined by two physical mouse buttons, and the oft-maligned "laptop nipple" resides in the center of the keyboard (for those who miss 90s IBM laptops). If you're not used to it, it can be frustrating during typing.

The webcam is an unexciting 720p affair, joined by a slightly more interesting IR camera array for Windows Hello functionality. There's also a multi-array microphone that functions as expected. A physical privacy shutter provides reassurance that no snooping eyes are watching through your webcam, although it's a somewhat low-tech solution compared to the camera-kill switches we've seen on other notebooks.

Security features are a big part of what makes this laptop special, though.HP SureView Reflect technology enables you to conceal your screen from prying eyes with a simple tap of F2, producing a reflective copper effect when the display is viewed from an angle. The Ryzen processor comes with AMD Memory Guard, which uses real-time encryption to protect against cold boot attacks, and HP Sure Sense uses AI-powered deep learning to help combat malware. HP has plenty of jargon on the subject, but the bottom line is that this laptop takes data security seriously.

Battery life is a decent 53Whr unit, providing up to 25 hours of standard use. Fast-charging via USB-C sees the battery fully charged from empty in barely over an hour. In practice, we got just under 13 hours of continuous use, with sound off and brightness at 50 percent—a solid showing for a professional laptop. On the topic of brightness, though, this display is a fairly basic 14-inch HD panel that fundamentally fails to excite. It's fine for its intended purpose, but don't expect to be doing digital art or color-correction work on this laptop.

For the busy professional who likes to stay on the move and maybe squeeze in a bit of gaming here and there, this new EliteBook is a great choice. The Ryzen chip performs exceptionally, and it's backed up by a selection of solid components. It's not the most exciting laptop we've seen, but it isn't trying to be; this is a sleek little corporate machine that could be a perfect fit for the business-minded among you. **–CHRISTIAN GUYTON**

VERDICT

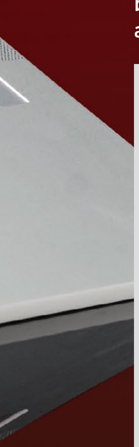
8

HP EliteBook 845 G7

+ ELITE FOUR Powerful professional processor; good security features; clean aesthetic.

– TEAM ROCKET No 1080p webcam; basic display; mouse nub sometimes gets in the way of typing.

From $1,399, hp.com



BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	561	1,448 (158%)
CrystalDisk QD32 Sequential Read (MB/s)	3,100	3,577 (15%)
CrystalDisk QD32 Sequential Write (MB/s)	557	2,337 (320%)
3DMark: Fire Strike (Index)	1,062	3,167 (198%)
Rise of the Tomb Raider (fps)	5	17 (240%)
PCMark 8 (index)	2,543	4,124 (62%)
Battery Life: Movie Playback (mins)	840	770 (-8%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our notebook zero-point is the HP Spectre X360, with an Intel Core i7-8565U, Integrated Intel UHD Graphics 620, and 8GB of DDR4-2400. *Rise of the Tomb Raider* is tested at 1080p at the highest graphical profile.

SPECIFICATIONS

CPU	AMD Ryzen 7 PRO 4750U
Graphics	AMD Radeon Vega Graphics
RAM	16GB DDR4 @ 3200MHz
Screen	14-inch IPS 1080p screen
Storage	256GB M.2 NVMe SSD
Ports	1x HDMI, 2x USB 3.2 Gen1 Type-A, 2x USB 3.2 Gen2 Type-C, headphone jack
Connectivity	Killer Wi-Fi 6, Bluetooth 5
Weight	2.93lbs
Size	0.7 x 8.5 x 12.7 inches

AOC's new C27G2 packs a 165Hz punch.

AOC C27G2

Punchy pricing for 165Hz, pity about that VA panel

BACK IN THE OLD DAYS of Intel's Netburst architecture, CPUs were all about operating frequency. MHz marketing descended into mania, and eventually Intel and the rest of the industry had a total rethink in favor of multiples cores and more work done per clock cycle. Are gaming monitors going the same way with an over-emphasis on high refresh rates? 360Hz monitors are now a thing...

However, the new AOC C27G2 is a 1080p panel that tops out at 165Hz, so it's firmly in the zone where there's an unambiguous benefit in terms of fluidity and input response compared to a 60Hz screen. The C27G2's job isn't to push the upper limits of high refresh gaming, it's to bring that buttery smooth 120Hz-plus experience to a wider audience.

Pegged around $260, this monitor combines that 165Hz refresh with a VA panel and a range of other features that look darned appealing on paper. The curved 27-inch panel is rated at 1ms for response and 4,000:1 for static contrast, as well as Nvidia G-Sync and AMD FreeSync adaptive refresh. Unsurprisingly given the punchy price point, G-Sync is inevitably of the "compatible" variety. Including an Nvidia decoder card in a monitor this cheap is essentially a non-starter.

Other highlights include a decent array of connectivity. HDMI and DisplayPort are both included, plus a VGA socket for old-school analog action. There's also a four-port USB 3.0 hub, the better to streamline peripheral connectivity and minimize cable clutter. All good, then? Not quite.

A closer look at the spec sheet reveals a peak brightness rating of just 250 nits. Even for an SDR display that's poor, let alone by HDR standards. If that's bad, the 1080p or 1,920x1,080 pixel native resolution is a case of pros and cons. On the upside, the modest pixel count means you don't need a $1,000 graphics card to achieve high frame rates. But stretched across a 27-inch diagonal, 1080p translates into just 82 pixels per inch and makes for fairly fat, ugly pixels.

But specs aside, is this a good gaming monitor? The impact of the 250 nit brightness rating is immediately apparent. The C27G2's lack of vibrancy and punch is all too obvious. At least the black levels are excellent. There's almost no backlight bleed. If you like playing games at night with the lights off, the C27G2 should probably be on your shortlist. If you often play in the day with lots of ambient light? Not so much.

AOC rates this monitor at 1ms for pixel response. But however you slice it, this doesn't feel like a 1ms monitor. There's too much blurring visible. That's true despite AOC including three switchable levels of response-accelerating pixel overdrive in the OSD menu. Even at the most aggressive setting the C27G2 still suffers from blurring, plus some tell-tale inverse ghosting indicating overshoot.

Bump the overdrive down a notch to "medium" and the ghosting largely resolves with little detriment to other aspects of response. But the slight blurring and smearing remains visible. The issue is at its worst in darker games.

The harsh reality, then, is that anyone who remembers the poor response of VA panels of yore will recognize the same issue in the C27G2's disappointing performance. That's a pity, because this is otherwise a nice monitor for the money. **–JEREMY LAIRD**

VERDICT

7

AOC C27G2

+ MEGA HERTZ Aggressive pricing; strong overall feature set; fluid rendering.

− MEGA HURTS VA panel lacks punch; mediocre pixel response.

$260 www.aoc.com

SPECIFICATIONS

Panel size	27-inch, 1500R curve
Panel type	VA
Native resolution	1,920 x 1,080
Refresh rate	165Hz
Contrast	3,000:1
Response	1ms
Brightness	250 nits
Inputs	HDMI 1.4 x2, DisplayPort 1.2, VGA
Other	G-Sync Compatible, FreeSync Premium, 4x USB 3.0 hub

Despite first impressions, this thing is divine.

Razer Tomahawk Mini-ITX

A chassis from Razer?

WHEN YOU THINK of Razer, the first thing that comes to mind is its peripherals: The DeathAdders, the BlackWidows, the Nagas, the Krakens. And then you have the Blade laptops, and the mouse mats, and that weird toaster thing it teased that one time (seriously). As a brand, it's established some impressively svelte products. But we never thought Razer would dabble in cases. It's a difficult field to crack, and often requires knowledge and experience to really become a truly top-tier chassis manufacturer.

That said, if you think about it from a business perspective, it makes a lot of sense. Razer's fanbase is one of the most dedicated, and that tri-headed snake commands a lot of respect. So why not dive into the realm of mid-range chassis, and produce something that iterates a lot of the company's already well-established design philosophy? We're talking sharp clean lines, beautiful finishes, and—perhaps unsurprisingly—a bevy of RGB lighting included as well.

And so here we are, with access to Razer's first ITX case. And for a first commercial attempt, in a brand new market segment, it's an interesting product that's—perhaps somewhat surprisingly—actually quite good.

We don't mean to say that in a disparaging way, but typically when a company dips its toes into a new segment like this, it takes time for it to really solidify its position in it. It's uncommon for a manufacturer's first product to completely hit the ground running. Nonetheless, the Tomahawk ITX has achieved this pretty well.

The Tomahawk comes in two designs: The ITX variant we have here, and the ATX version, with the former starting at $180, and the latter $200. So first things first, these are not cheap cases. For sure they're at the top of the mid-range stack. With the ITX variant, you get powder-coated steel, clean, sharp lines, tempered-glass panels that are magnetically sealed, underglow diffused RGB lighting (controllable via Razer Synapse), an illuminated Razer front panel, and an interesting internal layout.

It features support for up to a 240mm AIO in the roof, has mounting locations for up to six 120mm fans, and can even house three 2.5-inch SSDs in its seriously compact frame (it is utterly tiny). Official documentation states it can only support GPUs up to 320mm in length, but with a bit of tomfoolery we managed to sneak in our beefy Zotac GeForce RTX 2080 Super AMP Extreme, which clocks in at just shy of 324mm (albeit without a front intake fan installed in the case).

So what's it like to build in? Well honestly, for those used to building in cramped ITX conditions, it's a strong performer. There's plenty of wiggle room here, and it features a removable recessed radiator bracket to make AIO installation a doddle.

There are a few problems, however; the rear glass panel's magnets are a bit weak, especially given that there's very little room for cable management in the rear, and the PSU cable and mounting solution is frustrating to say the least, and feels like an oversight. And while the lighting is exceptional, our one bugbear is that you can't change the color of the front Razer logo, and by default it's green, which seems like a misstep (or a marketing ploy for an enhanced edition later down the line). You can find our full thoughts on the build process on PG68.

That said, for a first attempt it's darn impressive, and if you're a Razer fan, once you've gone through the process of building in it we've no doubt you'll fall in love with that epic styling and awesome, compact form. **–ZAK STOREY**

VERDICT

9

Razer Tomahawk Mini-ITX

⊞ **NEUTRON STAR** Impressive design; strong lighting; nice internal layout; good airflow; solid first attempt.

⊟ **SPACE DUST** PSU cable is annoying; front logo is fixed green; cable management needs work.

$180 www.razer.com

SPECIFICATIONS

Motherboard Support	Mini-ITX, Mini-DTX
2.5 / 3.5-inch Support	3x 2.5-inch drives
Max Radiator Support	240mm
Fan Support	6x 120mm
Dimensions (WxHxD)	8.1 x 12.7 x 14.5 inches
Graphics Card Clearance	12.59 inches (officially)
CPU Tower Clearance	6.49 inches

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Samsung 980 PRO 1TB

V-NAND SSD
980 PRO
PCIe 4.0 NVMe M.2
SAMSUNG ELECTRONICS CO., LTD.
1TB
SAMSUNG
MODEL MZ-V8P1T0

Samsung gives its premium SSD a PCIe Gen4 upgrade

SAMSUNG'S SSDs have been the standard by which consumer solid-state storage has been judged for several years now. So the arrival of a new "PRO" model from Samsung is quite the event. Hail the conquering hero, and all that jazz.

The new Samsung 980 PRO is particularly intriguing because this, ladies and gentlemen, is Samsung's first consumer M.2 NVMe SSD with PCI Express Gen4 support. The benefits of Gen4 are simple enough, namely a doubling of raw bandwidth. A wider interface doesn't automatically translate into more performance, of course. But on paper, the 980 PRO certainly claims to be making the most of the bandwidth bump.

Samsung reckons it's good for fully 7,000MB/s of sequential reads and 5,000MB/s of writes, both of which are far beyond PCIe Gen3's circa 4,000MB/s of theoretical throughput. However, those figures are for the 980 PRO's SLC write cache, a portion of the drive's memory allocated to run in single-bit per cell mode. In this 1TB model, the 980 PRO's firmware can allocate anywhere from 6GB to 144GB for high-performance SLC mode.

SLC write caches are widely used by SSDs, but not previously by Samsung's PRO drives. It's a consequence of the 980's switch from MLC NAND memory, which stores two bits of data per cell, to TLC memory, which packs in three. As a rule, the more bits per cell, the slower a NAND chip performs, and the lower its level of write endurance.

The change has forced Samsung to quote performance figures for both the SLC write cache and the underlying TLC memory. In the case of the latter, Samsung is claiming 2,000MB/s for writes, though reads remain up at 7,000MB/s. A further consequence of the switch is a downgrading of the 980 PRO's endurance rating. The 1TB 970 PRO was rated at 1,200TB of writes. For the 980 PRO, that's halved to 600TB. However, Samsung is maintaining the PRO line's robust five-year warranty with the 980.

Of course, peak throughput is just one part of the story, and arguably it's 4K random access performance that's both more important for the subjective feel of your PC and more in need of an uptick over existing NVMe SSDs. Here the claimed gains are more marginal, with the critical QD1 IOPS performance increasing to 22K for reads over the 15K of the old 970 PRO, and up from 55K to 60K for writes.

If those are the theoreticals, back in the real world the performance of the 980 PRO during our traditional pre-benchmark preparations is intriguing. In filling the drive entirely with data using large video files and an internal file copy method, the performance of the 980 PRO drops to around 1GB/s after around 50GB/s of data. Your mileage will vary according to usage and the specifics of Samsung's algorithms. But in the end, 1GB/s is in our experience the underlying internal performance of the drive once caching measures are exhausted.

Elsewhere, throughput is pretty insane. In CrystalDiskMark, the 980 PRO slightly exceeds Samsung's lofty claimed figures for sequential performance, making it an absolute beast of an SSD. It also puts in some pretty impressive numbers in Anvil's 4K metrics. It's not far off twice as fast as previous-gen SSDs for QD1 4K reads, while bumping writes by a useful 25 to 30 percent. Intel's novel 3D Xpoint-powered Optane drives retain the overall edge in 4K thanks to particularly strong read performance. But with the 980 PRO, Samsung has brought NAND-based drives a lot closer.

All of which means that our recommendation of this latest Samsung Pro drive is a bit more qualified than usual. Day to day, it's going to be a seriously responsive SSD. Throughput within the SLC cache is huge. But just occasionally, depending on your workflows, you may expose the underlying performance of the TLC NAND. And that might disappoint.

–JEREMY LAIRD

BENCHMARKS

	Samsung 980 Pro 1TB	Samsung 970 Evo Plus 1TB
Crystal Disk 6 Sequential Read/Write (MB/s)	**7,098 / 5,172**	2,788 / 2,331
Anvil 4K QD 1 Read/Write (MB/s)	**83 / 194**	48 / 141
Anvil 4K QD 2 Read/Write (MB/s)	**168 / 384**	91 / 281
Anvil 4K QD 4 Read/Write (MB/s)	**328 / 648**	152 / 524

Best scores are in bold. Our test bench consists of an AMD Ryzen 9 3800X, an Asus Crosshair VIII Hero, an Nvidia GeForce GTX 1080, 16GB of Corsair Dominator Platinum DDR4, and a Samsung 850 Evo 250GB OS SSD.

VERDICT 9

Samsung 980 PRO 1TB

+ **GREASE LIGHTNING** Crazy fast peak throughout; useful boost in 4K performance.

− **GOT GREASED** Underlying TLC performance not so spectacular.

$229 www.samsung.com

SPECIFICATIONS

Format	M.2
Interface	PCIe Gen4 x4
Control protocol	NVMe
Controller	Samsung Elpis
Capacity	1TB
Memory type	3D TLC NAND
Cache memory	1GB DDR4
Sequential Read Speed	7,000MB/s
Sequential Write Speed	5,000MB/s
QD1 read IOPS	22K
QD1 write IOPS	60K
Warranty	5 years

Asus ROG Strix Scope RX

Let's get optical

ASUS GENERALLY knocks it out of the park with its gaming keyboards, and the original Strix Scope from the Republic of Gamers brand was a typically solid outing. There weren't any unnecessary "unique" features, just a dependable all-round gaming board focused on nailing the simple stuff: Great build quality, responsive keys, and a sane price point.

The new ROG Strix Scope RX isn't trying to mess with that winning formula. In fact, it's visually almost indistinguishable from its predecessor, sporting the same clean design and sturdy construction materials: An alloy top plate and grippy PCB keycaps, with IP56-rated dust and water resistance for improved longevity. An RRP of $140 puts it comfortably in the premium range, but it's certainly not outrageous.

What it does do to set itself apart from its progenitor is hidden beneath the ROG font on those black keys. Asus has avoided the premium industry-standard of Cherry MX key switches here, replacing them with the new proprietary ROG RX Red switches. These optical-mechanical beauties use tiny light beams under each key to register actuation at the speed of light, resulting in near-zero input delay. If you hit that crouch key too late and get shot in a fierce *Warzone* match, you've got nobody to blame but yourself.

Optical switches aren't new (the most prominent competitor to the Scope RX is Razer's Huntsman series) but the ROG RX Red switches have an impressively sophisticated design. The lack of a metal electrical contact point extends the lifespan of each switch to 100 million keypresses, and a hollow-stem design with two x-shaped stabilizers results in keys with very little wobble that feel incredible to use. As the name suggests, these are linear switches that feel similar to the popular Cherry MX Red variants, with a good amount of force required to press and a 1.5mm actuation point.

The instant optical feedback and well-balanced resistance means that these key switches are amazing for twitchy shooters and platformers, but they're a genuine pleasure to type on as well. The hollow design allows for central RGB lighting under every key, which looks fantastic and can be customized in the ROG Armory Crate software, along with key bindings and macros. A small, transparent panel in the upper-right corner of the keyboard sports a light-up ROG logo and LEDs for lock functions.

The versatility of this keyboard is undeniable, despite its relatively minimalistic feature set. A quick-toggle switch feature lets you instantly swap F5 through to F12 from function mode to media-control mode, meaning that you won't have to be constantly holding Fn to adjust your volume. F12 doubles as a "Stealth Key," which hides all open applications and mutes all audio with a single tap—perfect for sly office gamers.

In terms of its overall layout, this is a full-scale keyboard squeezed onto a fairly compact chassis. There's zero flab to be found here, save for an enlarged Ctrl key designed for FPS games (which works great, by the way). Simple flip-out feet allow for two levels of alignment, and a USB 2.0 passthrough on the rear lets you plug your mouse or other peripherals in for reduced cable clutter behind your PC.

Few gaming keyboards are able to flawlessly execute the essentials and remain exciting without trying too hard to innovate. The Strix Scope RX feels fantastic to use and retains the same classy, uncluttered aesthetic of Asus's best keyboards, to the point where any criticisms we have just feel silly.

Yes, there's no included wrist rest, but you can pick up a decent one online for less than 20 bucks anyway. The ROG RX Red keys can be a little noisy if you're a speedy typist, but this is the case with almost any linear red switches. If you're looking for a durable, responsive keyboard fit for both grinding levels and grinding assignments, then the Scope RX is an undeniably kick-ass product.

–CHRISTIAN GUYTON

VERDICT
9
KICK ASS!

Asus ROG Strix Scope RX

+ **360 NO SCOPE** Awesome optical switches; durable build; refined aesthetic.

− **0% ACCURACY** No included wrist rest; some key clatter

$140, asus.com

SPECIFICATIONS

Switch Type	ROG RX Red Optical Mechanical Switch
Switch Durability	100 million presses
Media Keys	Integrated w/ function keys
Connection	Dual USB 2.0 w/passthrough
Battery Life	N/A
Wrist-rest	N/A
Dimensions	5.39 x 17.32 x 1.54 inches

Razer Pro Click Mouse

An ergonomic mouse made for comfort

RAZER HAS TEAMED UP with ergonomic experts Humanscale to create a mouse that is both beautiful and comfortable. With no RGB in sight, it's certainly a far cry from the usual Razer offerings, yet it's perfect to go along with its other professional keyboard and mousepad, the Pro Type and Pro Glide.

The Pro Type didn't impress us fully in our recent testing, but the Click might just be the saving grace. The white and gray styling completed with silver highlights makes the device look phenomenal. It is certainly one of the best-looking mice we have had on our table for some time. Even if after testing it this thing was a dud, we'd still use it as a beautiful paper weight, it just looks great.

Unfortunately it's only suited for right-handed use, due to the ergonomic design trying to reduce fatigue. It did feel rather bulky to start with, but after a brief bedding-in period we forgave it and let it force our hands into the position the mouse wanted us to be in. This made it extremely comfortable, and we were surprised at just how much comfort this style of grip provides. Both thumb buttons are easily accessible, the wheel tilt input is great, and the scroll wheel is both tactile and easy to use. You can reprogram all the buttons via Razer Synapse, which is a breeze and works as intended. If you log in, these settings will then save to a profile that can be downloaded and accessed on any other rig with Synapse installed.

All in all, the mouse sensor tracks well on all the surfaces we tried. We had no issues for the most part, and we didn't encounter any issues while in use for day-to-day office work or a touch of gaming. That said, while we were performing a latency test, there were some very slight inconsistencies with the results. Realistically though, these kinds of problem don't affect your typical day-to-day use, as it's a mouse that's solely aimed at the prosumer, rather than being designed for gaming fanatics. So nothing really worth worrying about on that front.

To charge the thing you are forced to use the included USB cable that Razer provides. It is just a micro USB cable, but for some strange reason Razer has decided that it'll be the only micro USB cable you can use with it, and has keyed the cable and mouse in such a way that no other cable we tried would fit. That's annoying. Why on Earth would you make it so that you can't connect any other cable to it to charge? As this is designed predominantly for professional use, in an office, home or even travelling environment, if you forget your cable, you're effectively stuffed until you get back home and source Razer's one.

LONG LIFE

The only saving grace is that after approximately 80 hours of use on the 2.4GHz wireless connection standard we ended up on around 50 percent total battery life. So the claim by Razer that it can do 200 hours on 2.4GHz and 400 hours on Bluetooth seems to be almost believable. Much like electric cars, longevity may vary dependent on temperature and environmental factors.

As we've mentioned, the Pro Click can be connected via 2.4GHz, Bluetooth or via the USB cable. Unlike the Pro Type, you don't need to have the USB dongle or Bluetooth on while the wire is plugged in, as the wire carries the data directly. It would have been nice to have a USB type-C cable rather than micro USB, both for faster charging and improved compatibility, but this isn't the biggest issue in the world.

Overall the mouse does everything it's meant to do and more. It's comfortable, it looks amazing, and it performs just as well in the office environment as it does while having yet another 30-minute cheeky gaming lunch break. If you are looking for a sleek wireless mouse that performs well, looks good, and can be used across multiple devices, you can't go far wrong with the Pro Click. Just don't forget your (almost) proprietary charging cable. **–DAVE ALCOCK**

VERDICT
8

Razer Pro Click

+ PRO CLICK Great connection options; very comfortable; one of the prettiest mice on the market.

− NO CLICK Almost proprietary connector.

$99.99, www.razer.com

SPECIFICATIONS

Sensor Model	Razer 5G Optical
Max Sensitivity	16,000 CPI
IPS	450
Acceleration	40 G
Programmable Buttons	8
Connection Standard	USB Type-C, 2.4GHz wireless, Bluetooth
Battery Life	160+ hours 2.4GHz, more with Bluetooth
Weight	0.23 lbs

Razer Pro Type Keyboard

A keyboard for professionals. Maybe

RAZER IS OFTEN either loved or hated. It can either do no wrong or it can't get anything right. It has a strange status within the tech industry that we don't really understand—we've seen great products from Razer and some less so, just like every brand.

Recently Razer has decided to target the prosumer market with the Pro Type keyboard, Pro Click mouse, and Pro Glide mouse pad. While many people are currently working from home it's definitely a great time to target those who want to have beautiful peripherals at work. The Pro Type keyboard is a stunning bit of kit, and aesthetically you could quite easily mistake it for an Apple product. The silver top plate and white keys really do make it a very sleek product, and the clean white backlighting tops it off. It certainly ticks all the boxes if you want a clean-looking board.

The Pro Type is a full-sized board with Razer Orange switches. These switches are tactile, with an actuation force of 45cN, a 4mm travel distance, and a 1.9mm actuation distance. It is very similar to a Cherry MX Brown, but the switches are slightly lighter. The switches are really nice to type on, and are great for the office setting where you don't want a click but do want feedback. The only negative is that they are slightly scratchy if you are very slowly compressing the switch. On top of the switches sit some rather beautiful white soft-touch keycaps. These are actually really nice to use, and we certainly can tell the difference compared to the standard ABS/PBT caps. It will be very interesting to see how long these keycaps last under intensive use, though so far they feel as good as new after two weeks of vigorous testing.

Although the switches are quiet, unfortunately the keyboard resonates a horrible metallic sound when you're pressing larger keys that have stabilizers. You can also force this problem by knocking the metal top plate. Until it is noticed it isn't an issue, but as soon as you realize it's there it's awful.

The Pro Type is wireless and has Bluetooth and 2.4GHz connection options. It's extremely easy to switch between three Bluetooth devices with the FN+ 1-3 keys, and you can also have another device connected via the 2.4GHz dongle. We did have some latency issues via Bluetooth and on occasion had to re-pair the device, but no more than usual. For some strange reason, you can't actually connect the board via the included USB type-C cable for anything other than charging. We can't fathom why this isn't also an option, as it would give you a fifth connection. It would also mean that on the computer you use the most you could just use it while you charge it, and then every other system, phone, TV, tablet, laptop etc. could just be connected wirelessly. As it stands, you must have the charging cable *and* either use Bluetooth or 2.4GHz connection to charge and use the keyboard simultaneously.

Using Synapse you can customize the functions of the keyboard almost endlessly, and with the Hypershift function you can even have two layers. Although we're not a fan of logging into software, it does allow you to carry your settings to other computers if you also log in there.

Overall, the keyboard does tick many boxes for a prosumer. The wireless options are great, and the battery life with the lights set to low is more than acceptable. In terms of aesthetics, wireless connectivity, switches, software, and keycaps it ticks all the boxes. However, not being able to run it via the wire, and more importantly, the horrible resonating noise just let it down. So close, so close. **–DAVE ALCOCK**

VERDICT 7

Razer Pro Type

⊕ PRO TYPE Great connection options; fantastic feeling switches and keycaps; looks beautiful, especially with the other products of the same line.

⊖ NO TYPE Horrible, horrible resonating noise; no standalone wired option.

$139.99, www.razer.com

SPECIFICATIONS

Form Factor	Full size
Switch Type	Razer Orange Tactile Mechanical Switch
Switch Durability	80 million
Media Keys	Integrated via FN keys
Connection Standard	Wireless
Battery Life	12hrs (full backlight), 70hrs (backlight off)
Weight	31.7 Oz
Dimensions	17.4 x 5.2 x 1.6 - inches

Corsair K60 RGB Pro

World: Meet the Cherry MX Viola

THERE HAS BEEN an absolute mob of different key-switch types launched since mechanical keyboards first made their mainstream appearance in 2013. It seems almost endless, and Cherry, although a bit more reserved on this front, has been no different. The company has launched two switches since 2013—the MX Silver or Speed, and its Low Profile variant, which was effectively just a redesign of its MX Red.

For those that don't know, back when the furore around mechanical boards kicked off properly and the market boomed in 2015, Cherry began to struggle to keep up with the demand for its switches. Corsair, seeing this problem, stepped in and offered to buy Cherry an entire factory line for free to help soothe some of its demand woes, in exchange for priority on Corsair's own orders and exclusive access to the new switch types Cherry was developing. Thus, a relationship was formed between the two companies, and since then almost all but one of Corsair's keyboards have stood by the tried-and-true mechanical switch manufacturer. In fact we've only just seen OPX launch, which is Corsair's first switch design, built and designed in-house, in its flagship K100 keyboards.

So, when Corsair reached out to us with a barrage of new products to review, this one in particular caught our eye. This here is the K60 RGB Pro. At first glance, it's not that spectacular. That's not to say it's not good—in fact it's really good. The design is excellent, the aesthetics are impeccably clean, the feature set is strong, and it comes in at a fair and balanced price. But it's not meant to be one of those flagship products. It hasn't received the same fanfare as the K100 did for instance, or the original K70. But it does come with a brand new switch type: The Cherry MX Viola.

PITCH PERFECT

So what exactly is Viola? Well, it's a linear switch with a completely redesigned internal layout, forsaking the stem in favor of one built into the actual housing. It is a clear polymer, allowing light to shine through it, and it features support wings on each side of the cross that mounts the keycap. It actually officially launched back in January, but this is the first time that we have seen it featured in a physical product. Cherry said in its press release that it's aimed specifically at the lower end of the market, in an attempt to replace those far cheaper membrane boards. And the thing is, it's seriously impressive.

It sounds nice, feels good, has a 2mm actuation point, requires 45cN of force to actuate, increasing to 75cN at the end of its travel (4.0mm) for quick rebound. So it's not too dissimilar to an MX Red in a lot of ways. On top of that, Corsair has paired this with a set of super-low-profile keycaps, which make it very quick to type on, and it sounds ridiculously good. For a linear, budget switch, this is an awesome addition, and it is close to being this editor's favorite.

So the downsides for the whole setup? Well there's no mention of lifetime or number of keypresses just yet, and the keyboard itself does lack dedicated media keys (which is a bit of a nuisance, yet somewhat expected at this price point). But all in all, the overall design of the K60 RGB Pro, mixed with that relatively low price point and stellar switch, makes this a sure-fire win for anyone who wants to dip their toes into the world of cheap and affordable mechanical keyboards, without losing that satisfying, premium feel. **–ZAK STOREY**

VERDICT 9 KICK ASS!

Corsair K60 RGB Pro

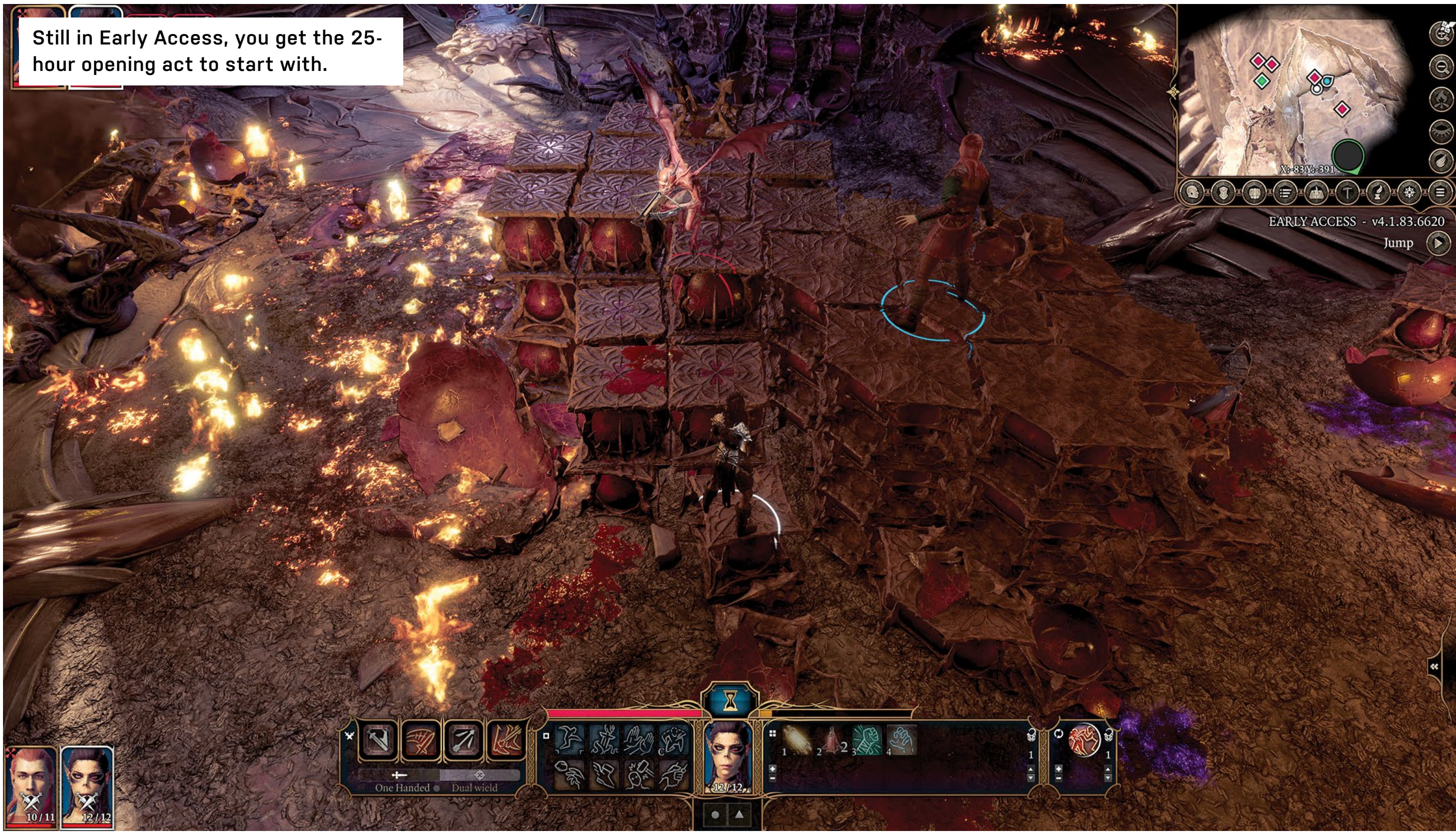
➕ **TAGELHARPA** Impressive switch; clean design; strong price point; impressive software suite; sturdy.

➖ **TRIANGLE** No wrist-rest; integrated media keys.

$90 www.corsair.com

SPECIFICATIONS

Form Factor	Full Size
Switch Type	Cherry MX Viola
Switch Durability	N/A – 2 Year Warranty
Anti Ghosting	Full NKRO 100%
Media Keys	Integrated
Connection Standard	USB 3.1 Type A
Weight	3.1 oz



Still in Early Access, you get the 25-hour opening act to start with.

Baldur's Gate III

Remembering the Forgotten Realms

RELEASING BALDUR'S GATE III into Early Access might be a masterstroke. It's going to be there for about a year, and while it gets the 25-hour first act into players' hands in a playable state, it also lets developer Larian off the hook for any glitches—like the fact we couldn't get the game to run under its default Vulkan renderer, backing off to DirectX 11 instead. There's a disclaimer up front and a darn great watermark on all screenshots to the effect that, yes, this is still an early build.

Look at it, then, as a valuable opportunity to watch a master at work. Or wait a year before buying. What you get now is a remarkable opening sequence involving a flying mollusc-ship and dragons right out of Westeros. Some mind flayers—levitating, tentacled, evil creatures with a nice line in psychic domination—have captured you and some other characters and implanted one of their tadpoles behind your eye. In a few days, unless "cleansed," you'll turn into a mind flayer yourself. We suspect "cleansed" doesn't involve scented candles and a big syringe full of coffee, but everyone you meet seems to have a different plan to get the bug out of you, and some will make things far worse. The actual city of Baldur's Gate remains off limits, for now.

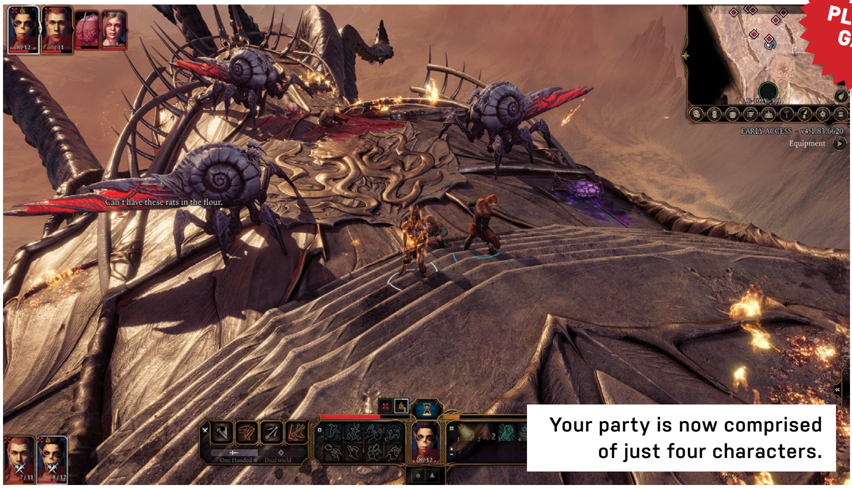
It's been 20 years since *Baldur's Gate II*, and Larian's return to BioWare's setting has raised a few questions. Is this just *Divinity: Original Sin* with a Forgotten Realms, *Dungeons And Dragons* 5th Edition wrapper over the top? In some ways, yes it is, as your party size has dropped to four from six, and the script crackles with lines—and non-verbal communication—that we've never got before. However, the game is still very keen to ensure you know there's a dice-rollin' RPG running underneath, with virtual 20-sided dice appearing on-screen to hammer home the fact that your actions are sometimes subject to randomness. Passive skill checks happen behind the scenes, as you desperately try to read mysterious sigils on the mind-flayer ship but get nothing but messages telling you you've failed. Critical hits in combat also summon the D20, slashing it in half when you score a particularly brutal wound.

Combat sees the previously real-time game change to a turn-based mode, the order of battle drawn up using a series of portraits at the top left of the screen. Your character can carry out one action, such as a sword slash or bow shot, then a bonus action like jumping, and move a certain distance before their turn is over. You rotate through your party, and the bad guys get their turns in the order determined by the portraits until you've won or your party is killed. Downed party members can be "helped" back to their feet by an ally, but are left with just one health point unless they can drink a potion or receive a healing spell.

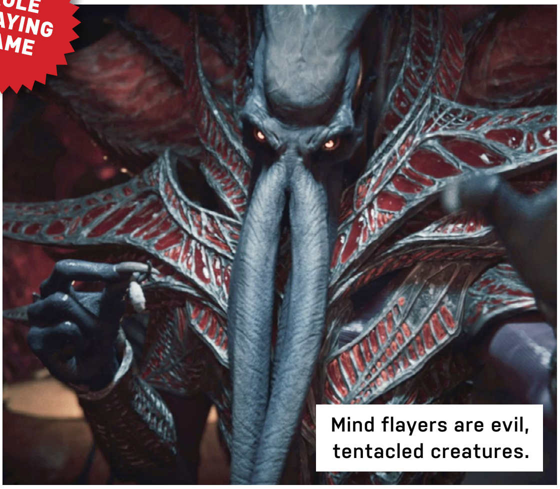
Aboard the mind-flayer ship, combat consists of fending off intellect-devourers—Cronenbergian crosses between spider and brain—as well as imps from the hell dimension you are passing through. The whole thing is distressingly icky, easily the most squelchily biological opening to a game we can remember, as you encounter brains in jars, cerebral aquariums (whatever the hell they are) and the flayers' discarded, mind-controlled minions, some with the top of their skull removed and the brain exposed. This makes it sound like a horror

© LARIAN STUDIOS

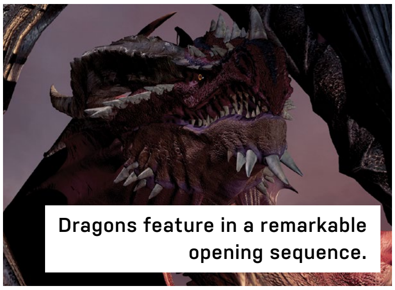
ROLE PLAYING GAME

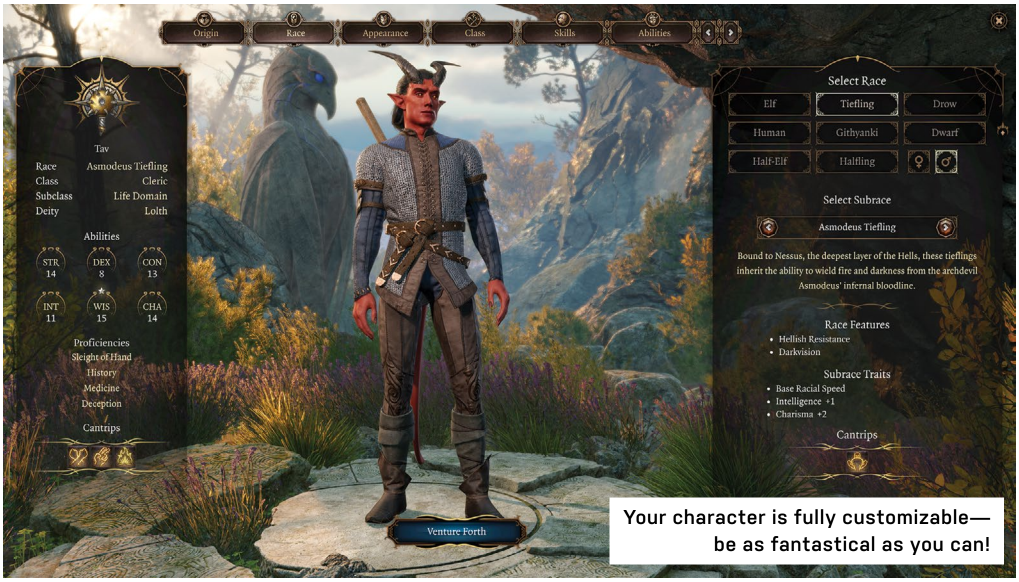

Can't have these rats in the flour.

Your party is now comprised of just four characters.


Mind flayers are evil, tentacled creatures.

Find yourself on a flying squidship.


Dragons feature in a remarkable opening sequence.



Tav

Race Asmodeus Tiefling
Class Cleric
Subclass Life Domain
Deity Lolth

Abilities

STR 14
DEX 8
CON 13
INT 11
WIS 15
CHA 14

Proficiencies
Sleight of Hand
History
Medicine
Deception

Cantrips

Select Race

Elf
Tiefling
Drow
Human
Githyanki
Dwarf
Half-Elf
Halfling

Select Subrace

Asmodeus Tiefling

Bound to Nessus, the deepest layer of the Hells, these tieflings inherit the ability to wield fire and darkness from the archdevil Asmodeus' infernal bloodline.

Race Features
- Hellish Resistance
- Darkvision

Subrace Traits
- Base Racial Speed
- Intelligence +1
- Charisma +2

Cantrips

Your character is fully customizable—be as fantastical as you can!

game, and perhaps it is—there's a vicious beast tunnelling away at the cerebral tissue behind your eye, remember.

FOUR IS A PARTY

Following the inevitable crash of the squidship, however, things take a distinctly traditional turn. Saved from a head-first plunge by mysterious magic, you find yourself wandering on a beach. It's so reminiscent of the beginning of *Original Sin 2* you might think that Larian has got its wires crossed, but it soon becomes apparent that Larian is determined never to let the pace drop. You encounter further survivors of the crashed cephalopod, and are reminded just how deep a character it's possible to portray with this many lines of dialogue. It helps that certain characters, such as the explodey wizard or the vampire elf, are placed there purely to keep the conflict coming. We remember picking up a Chaotic Evil wizard in *Baldur's Gate II*, and debating whether to keep him in the party for his undeniable combat powers, or leaving him by the roadside because he was clearly a bad one.

Having only four in the party means that these decisions are now more agonized than ever before, but the pressure is taken off as characters can be added to your camp and slotted in and out of the active party, or just spoken to at will. Your character, meanwhile, is an entirely custom creation, and it's possible to create a range of handsome elves and oddly twisted halfling women. A Larian survey, however, discovered that the most commonly created characters were vanilla humans—so in the name of *Maximum PC*, try to get some lumpen weirdness into your characters.

Perhaps this method of release—episodically under the Early Access banner—will turn out to be the best possible way to experience a 60-hour-plus game. Get it now, experience the beginning, then have a bit of a rest before a content patch delivers the next act. Early Access saves will not be compatible with the final release, so there's the opportunity to play the game at least twice—perhaps once as an evil spellcaster before going all goody-goody swords-dwarf on the second. You may follow the same broad plot, but the emergent situations are likely to be very different. There's often more fun to be had being evil, and Larian has surprises in store for every possibility. **–IAN EVENDEN**

VERDICT 9

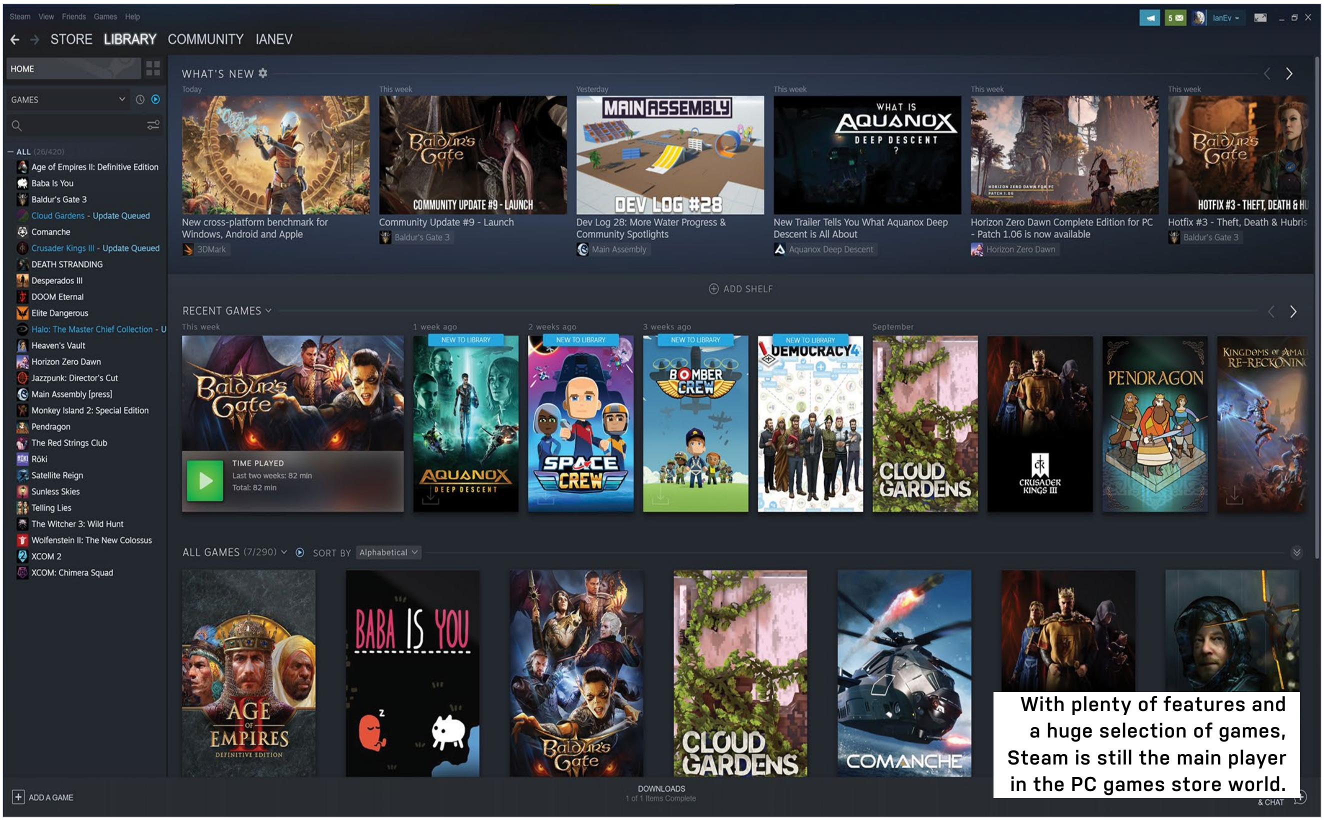
Baldur's Gate III

+ MINIATURE GIANT SPACE HAMSTER Sprawling fantasy world full of interesting creatures to set on fire.

– BRAIN IN A JAR Early Access means a few bugs, and the game is incomplete.

RECOMMENDED SPECS CPU, Intel i7 4770k / AMD Ryzen 5 1500X. RAM, 16GB. GPU, GTX 1060 6GB / AMD RX580.

$60, https://baldursgate3.game, M-rated


Steam View Friends Games Help
STORE LIBRARY COMMUNITY IANEV
HOME
GAMES
ALL (26/420)
Age of Empires II: Definitive Edition
Baba Is You
Baldur's Gate 3
Cloud Gardens - Update Queued
Comanche
Crusader Kings III - Update Queued
DEATH STRANDING
Desperados III
DOOM Eternal
Elite Dangerous
Halo: The Master Chief Collection - U
Heaven's Vault
Horizon Zero Dawn
Jazzpunk: Director's Cut
Main Assembly [press]
Monkey Island 2: Special Edition
Pendragon
The Red Strings Club
Röki
Satellite Reign
Sunless Skies
Telling Lies
The Witcher 3: Wild Hunt
Wolfenstein II: The New Colossus
XCOM 2
XCOM: Chimera Squad
WHAT'S NEW
New cross-platform benchmark for Windows, Android and Apple
3DMark
Community Update #9 - Launch
Baldur's Gate 3
Dev Log 28: More Water Progress & Community Spotlights
Main Assembly
New Trailer Tells You What Aquanox Deep Descent is All About
Aquanox Deep Descent
Horizon Zero Dawn Complete Edition for PC - Patch 1.06 is now available
Horizon Zero Dawn
Hotfix #3 - Theft, Death & Hubris
Baldur's Gate 3
ADD SHELF
RECENT GAMES
TIME PLAYED
Last two weeks: 82 min
Total: 82 min
ALL GAMES (7/290)
SORT BY Alphabetical
ADD A GAME
DOWNLOADS
1 of 1 Items Complete

With plenty of features and a huge selection of games, Steam is still the main player in the PC games store world.

Steam vs Epic Games Store

Digital storefronts battle it out for your money

FROM ITS LAUNCH in 2003, Valve's Steam digital game store has had things pretty much its own way. In 2013 it held 75 percent of the market, and in 2017 represented 18 percent of global PC game sales. In 2019 it had 95 million active monthly users. It has branched out into game controllers, gaming boxes and even an operating system. If there was ever any doubt that PC gaming is huge, then Steam is all the evidence you need.

There have been competitors, of course. Who remembers Games For Windows Live? They have tended to be single-publisher stores, however, such as Ubisoft's Uplay and EA's Origin. It wasn't until 2012 that it got competition, when GOG—a previously retro-only store operated by *Witcher* developer CD Projekt—began selling more recent titles. Then, in December 2018, the Epic Games Store followed *Fortnite* by moving in on the game store scene.

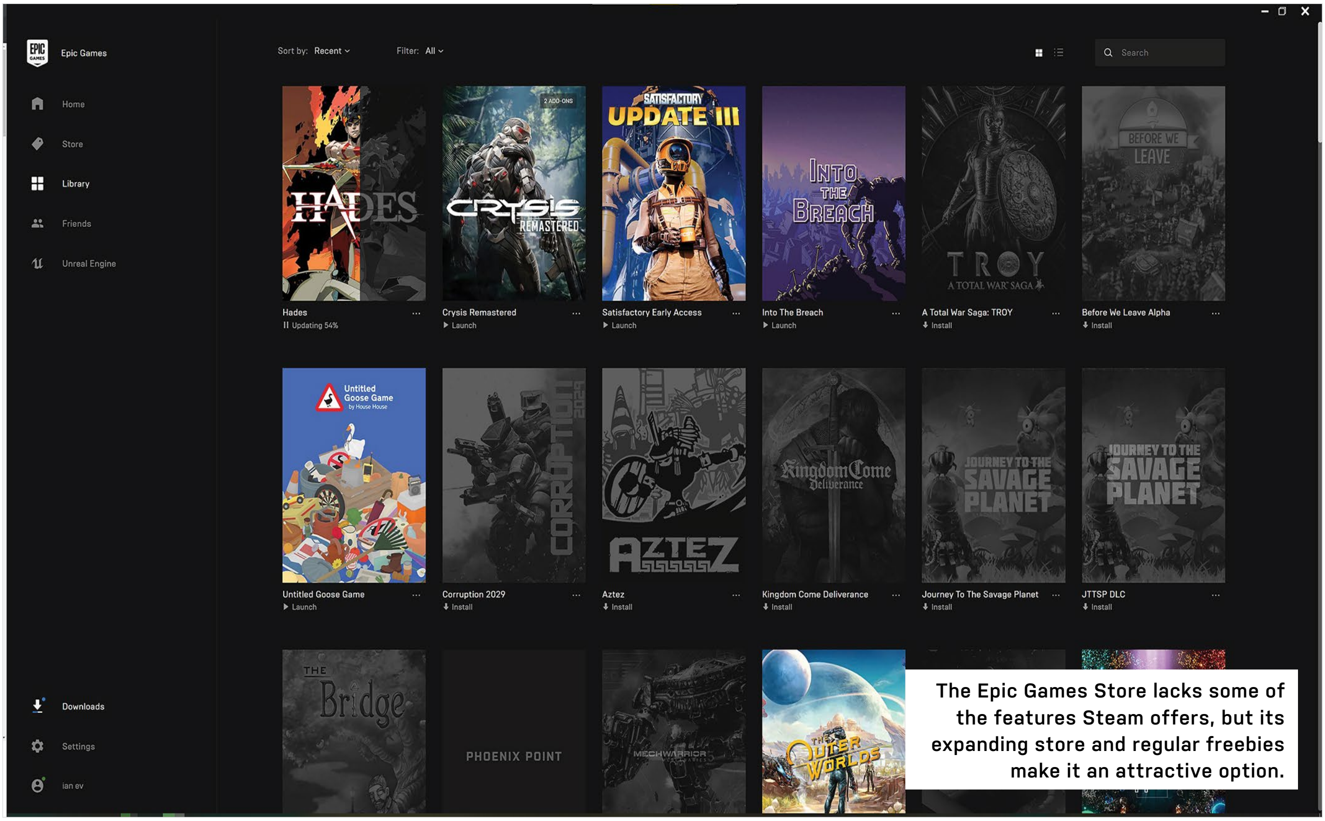
Epic brought with it one simple promise that made it attractive to gamers: Free games. Not free-to-play games like *Fortnite*, but paid-for titles, given away for free. This program began in 2019, and there's generally one or two a month, depending on the games' age ratings—if the main title shuts out younger players, another will be made available alongside it with lower requirements—rolling over on a Thursday. They range from tiny indie offerings such as *Abzu* or *Into The Breach* all the way up to *Grand Theft Auto V* or the *Batman Arkham* games. The free games have kept coming throughout 2020, though there's no evidence they will continue to do so perpetually.

Both stores are free to download, so there's no problem with having both apps installed on your PC. Some developers choose to sign exclusivity agreements, the first of which on Epic was *Metro: Exodus* from 4A Games. That title has since appeared on Steam, but others have taken its place, such as Creative Assembly with *Total War Saga: Troy*. This game was released for free on the Epic Games Store for one day, before reverting to full price. It is listed as "coming 2021" on Steam, but with no further details. For other titles, prices may be different across storefronts, and it's always worth checking a publisher's store as well in case one of the outlets is having a sale on a title you particularly want.

If it's a niche title you're after, then Steam is your best bet. Its catalog of over 34,000 games (2019 figures) means it will almost certainly have what you're looking for. Epic's offering is a little more streamlined, although it gets wider every day. This means that Steam is a little better for discovery—Epic's "browse" mode allows you to narrow down the games or view by genre, plus features such as co-op or controller support, but Steam has all this and more besides, with tags, wishlists, curated lists of games from users, and lists of top sellers in each category. There are algorithmic recommendations too, based on the games you've already got in your library, and you can leave a review if you fancy writing one. Steam also sells physical gift cards, if you're looking for a present for the PC gamer in your life as the holiday season approaches.

Community features also tend to be stronger on Steam. Epic's system offers to import your friends list from Facebook and Steam. There's a text chat

© STEAM


Epic Games
Sort by: Recent
Filter: All
Search
Home
Store
Library
Friends
Unreal Engine
Downloads
Settings
ian ev
Hades
Updating 54%
Crysis Remastered
Launch
Satisfactory Early Access
Launch
Into The Breach
Launch
A Total War Saga: TROY
Install
Before We Leave Alpha
Install
Untitled Goose Game
Launch
Corruption 2029
Install
Aztez
Install
Kingdom Come Deliverance
Install
Journey To The Savage Planet
Install
JTTSP DLC
Install
PHOENIX POINT

The Epic Games Store lacks some of the features Steam offers, but its expanding store and regular freebies make it an attractive option.

system too, but little more. Steam, on the other hand, not only pulls in news from the internet to display on each game's storefront, but allows sharing of screenshots and in-game videos, group chat, and breakdowns of each game's social features. Then there are achievements, a metagame that puts players in direct competition with each other to see how many they can win and how quickly. All major console platforms have these, and it's good to see the little popup in the corner of the screen when you win one. They're also perfectly possible to ignore completely. Then there's the Steam Workshop, full of user-generated content. Epic is much newer, of course, and may well have features such as these in development.

THE OTHER SIDE

But while Steam might be a nicer place for gamers to hang out, it looks a little different from the other side. Both stores take a cut of developers' income from any games sold. Steam takes a flat 30 percent for the privilege of using its storefront—the same rate Apple charges developers on its App Store—which then drops if a game sells more than 10 million copies. Steam's policy in this area has attracted criticism in the past, as it has not wavered as the cost of network delivery has become cheaper. Epic, having initially postulated that its commission could be as low as eight percent, takes a cut of 12 percent, with further discounts for games created using the Unreal Engine, which is also owned by Epic. Figures from market intelligence company NewZoo suggest that PC gaming is worth $33 billion annually, and even if Steam's 75 percent share of digital downloads has been eroded by canny competitors such as Epic, that commission is enough to make big money for the distributor.

From a player's point of view, it's worth going to whichever storefront is offering the game you want for the lowest price. If online multiplayer is important to you, then go where the community, or your friends, are playing. Both stores are equally efficient at delivering patches, and on residential broadband connections there's no difference in the speed at which things download—although anecdotal data on the internet suggests that Epic has the edge on fast broadband lines. The specs we list below are for running the client app itself; each game will have its own list of computer specs needed to run, often climbing into "dream machine" territory—although remember that many games will run perfectly well on mid-grade hardware at 1080p and medium settings.

What Epic is doing, however, is similar to what AMD recently did to Intel. A bit of competition in the marketplace does wonders for a firm's ability to update its products, and anything that incites Valve to improve what's already a very good product can only be a good thing for players. **–IAN EVENDEN**

VERDICT 9

Steam

+ LIQUID Enormous catalog; great community features; user-generated Workshop.

− VAPOR Sometimes a dominant position can stifle innovation.

RECOMMENDED SPECS CPU, Pentium 4 3.0GHz or better. RAM, 1GB. GPU, 512MB+ VRAM and DirectX 10-compatible.

$Free, https://store.steampowered.com

VERDICT 8

Epic

+ UNREAL Free games!!!! Takes less from developers; could its downloads be any faster?

− NOT REAL Not as wide a range on offer; lesser community; no UGC; no achievements.

RECOMMENDED SPECS CPU, Core 2 Duo / Athlon 2x2 or better. RAM, 2GB. GPU, Geforce 7800 / Radeon HD 4600 / Intel HD 4000 .

$Free, https://www.epicgames.com/store

© EPIC

LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Coolant Investigations
> Alternative Picks
> Death of the Disc Drive?

Strange Buildup in Tubes

To Whom It May Concern: As with a letter from a reader in your previous issue, I am also incarcerated in MDOC. Though, I'm not sure if we are in the same "M" state. I'm having a third party email this to you for me instead of writing a letter, and appreciate any feedback you can provide.

A couple of years before my arrest in 2014, I built a liquid-cooled PC. I was one of the first people to get a new coolant to test from Mike at Mayhems. It was their new Pastel UV Lime Yellow coolant. And while I loved the color with and without my UV lights on, I kept having the same issue with my tubing. I kept having a strange buildup collecting in my tubes and reservoir even after a vinegar solution flush, a baking soda solution flush, two distilled water flushes, and a rebuild that switched from Primochill Advanced LRT tubing to Primochill Clear Acrylic tubing.

I was in talks with Mike at Mayhems on Overclock.net to try to duplicate the issue on his end when I was arrested. Sadly, I was never able to figure out the problem. Though, we did think it may have been because of the type of UV lights I was using.

My build logs can be found at Overclock.net under the username "Stuntfly02." Could you maybe contact Mike and see if he remembers me and was ever able to figure out what the issue was? It will be another six years until I am able to get back out there and be able to look into things myself. I would appreciate a reply sent to me at the email address below.

Thankfully until then, I have your wonderful magazine to keep me up to date on the world of computers. Thank you for all of your hard work. Stay safe and keep it up.

–Paul Torretti

EDITOR ZAK STOREY RESPONDS: Wow, that's one heck of a story you've got there. So I reached out to Mike, and he does indeed remember you, and Mayhems has actually since found out what was causing the problem, way back then.

Apparently the issue was the Pastel coolant base utilized ZNO (zinc oxide), this reflected light back into the system, and the dye used at the time absorbed certain wavelengths of UV light. In conjunction with the fluid, that created an ultra-wide band of light that reacted with the ZNO, causing it to conglomerate (the brown stuff on the tubing). The tubing also was part of the problem as well, but changing the color of the coolant slightly managed to fix the issue.

What they did was add a blocking material to the coolant that allowed only a certain wavelength of light to reflect back in, which fixed the issue. Mike goes on to say that he wants to thank you for pointing him to the problem, as it was something they'd never seen before, or even thought of.

As a side note, Pastel is now being discontinued, and a diluted form of the XTR coolant we were testing a couple of issues back will be replacing it, for enhanced performance, and stronger and more intense colors going forward. In fact I think it's almost ready to go on sale, judging by Mike's social media updates.

Alternative Solutions

Hey Zak. Have been enjoying the magazine since the 1990s. Some of the first I read I picked up in airports before I got a subscription. It would be great if you had a woman on your staff. I enjoyed and appreciated Joanna's writings.

My suggestion is on the PC builds, why do you not offer alternate mobos, CPU and GPUs? The rest of the build, cases, SSD, HD, power supply are for the most part commodities that can be found easily. I concentrate on pairing the CPU, the mobo, and GPU. So let's say your build uses the AMD Ryzen 7 3800X like in the "Mystical Monster" build in the 12/2020 issue. Suppose I do not want to spend $760 on the Nvidia RTX 3080? Can I use another GPU that costs less but won't throttle fps?

–Rod Marchese

EDITOR ZAK STOREY RESPONDS: This is something we've discussed

↘ submit your questions to: comments@maximumpc.com among the team quite a bit. In fact we've done it a few times with some of the bigger features, where we'll recommend different components alongside the parts we have picked. I think the bigger worry stems from the fact that because we haven't got hands on with those parts, it's hard for us to recommend them in that manner for a particular build. It's an interesting point you raise though: Most of the time we do comparisons like that, it's because we're trying to offer two sides of the coin—Intel vs AMD, etc.—but yeah it's definitely worth taking a look at in the future. Perhaps as a little boxout on the side.

In regards to the latter, I think the problem is depending on where you look at the price spectrum you're going to see significant dips in graphical performance. This actually might be worth doing a feature on. But it essentially depends on what frame rate you're trying to target. So for instance if you're after 200fps at 1080p, lower-powered processors will certainly hinder that effort as you're likely to throttle the processor trying to hit that frame rate. Theoretically you could get away with a quad-core processor at 4K and an RTX 3080 just fine (in fact that's part of the reason why my own home system runs a Core i5 and an RTX 2080 Super, because I'm primarily gaming at 3440x1440), and you'd likely not see huge leaps and bounds by going up to something like an eight-core or 10-core chip.

In contrast, the reverse is true if you go the other way, with low resolution, high frame rate. You could likely get away with an RTX 3070, but you would need a higher core count—six to eight—chip to ensure that the processor is not causing a bottleneck in order to hit that frame rate. There's definitely a feature in this when we get better access to testing platforms again (i.e. our main HQ).

But no, I'll take this into account, I'm sure there's something we can weave into the Build It segment, because I agree that it does make a lot of sense.

No More Disc Drives?

Lately I've noticed that your builds don't include a CD or DVD drive. They don't appear in the build's list of parts. It also appears that there isn't a slot for them in the cases?

Am I missing something or is there a reason for this?

–R.T.

EDITOR ZAK STOREY RESPONDS: It's one of those things really, the changing times have pushed the humble disc drive out of the limelight. It's a trend we've seen that started around six or seven years ago. PC development as a whole, in fact this entire industry, is really driven by PC gamers. Everything from processor and GPU performance to storage all basically spins around that platform. It generates a significant chunk of revenue (outside of the server market), and getting that marketplace to buy repeated upgrades year on year is a big part of the industry ethos.

Because internet speeds have increased over the years, and games are now predominantly downloaded instead of installed via discs, the need for disc drives has diminished. When it comes to case design in particular, having a chunky 5.25-inch drive bay at the front of the chassis, takes up a lot of space, and again as the community has turned more and more to the world of liquid cooling in the form of AIO radiators, and processors have got hotter, the need for more space to effectively cool that is important, and so we have generally seen the slow departure from disc drives entirely.

That's not to say that they're not useful still—they're a perfectly good option if you want to back up media, or if your internet bandwidth isn't quite as potent—but even from our perspective we'd recommend a good-quality external disc drive if you need one, as opposed to one integrated into the case itself. That way, you've always got one to hand that you can plug in and use via USB if you need to, and you don't lose out on any of the modern features found in more current designs of chassis.

On top of that, a significant proportion of manufacturers have pivoted their factory lines away from producing cases with space for a CD or DVD drive. That's not to say there's none out there—Fractal Design, Phanteks, and be quiet! do have chassis available that feature them, and are also packed with modern design features and have plenty of support for cooling too (particularly the Dark Base Pro 900, the Enthoo Pro M TG, or the Fractal Design Define R7).

It's sort of like the RGB phenomenon. Manufacturers made a lot of their flagship products RGB, and therefore you had no choice but to buy it with RGB. Profits go up on the RGB stuff, the company sees that, and then makes more of its products RGB, and so on, until eventually everything has RGB. The same phenomenon can be seen with the disc drive slowly fading away from modern cases.

If you're after a good USB disc drive, I'd recommend popping over to Amazon and picking up its recommended External DVD Drive with USB 3.0 connectivity. That should suit all your needs. It's slimline too, so it's very easy to store when you don't need it.

[NOW ONLINE]

BEST RASPBERRY PI ACCESSORIES

You can purchase a Raspberry Pi for as little as $5 (for the Raspberry Pi Zero) or more likely $35 (for the Raspberry Pi 4), but you'll need a few extra products to make it run. And, beyond that, there's a whole world of accessories that help you make the most of your Pi.

As with any computer, on the Raspberry Pi, you'll need a way to enter data and a way to see the interface, which usually means getting a keyboard, a mouse, and a monitor.

Read the full article here: http://bit.ly/RPiAccessory

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THE BUILDS

WITH THE BUILDS WELL AND TRULY SHAKEN UP by our dear editor last issue, it's now time to introduce some new cases. The Intel and AMD builds at each price range will still share the same case, and for our budget systems it's the simple but effective Corsair 4000D Airflow.

Following last month's changes, we're now focused on trimming the price and making small improvements. Multiple price drops on components in both builds (CPUs, our power supply, and the ASRock mobo in the AMD build) have given us a bit of money to play with, but we're keeping it sensible. A motherboard shift from Gigabyte to ASRock in the Intel build helps us make a further saving, and both builds have new memory: Ripjaws Series V in the AMD machine, and TeamGroup T-Force Dark Z in the Intel one, saving five and nine bucks respectively. We've dialed the memory speed in the Intel machine back to 3,200MT/s; if you can find a cheaper DDR4-3600 kit then great, but the Core i5-10400 won't benefit as much from the higher speed compared to the Ryzen.

Our GPUs have had a swap; the AMD RX 5500 XT 4GB card is back in the AMD build, although it's a different (read: cheaper) model from XFX this time. The Intel build also has a more affordable GPU, MSI's Ventus XS version of the GTX 1650 Super. These two cards should have near-identical performance, averaging around 60fps at 1080p Ultra—thanks to Jarred as always for the numbers.

The last adjustment we've made is to the drives. 250GB ain't bad, but 500GB is better, and we've doubled our SSD storage without much price alteration. Gigabyte's Aorus Gen4 500GB SSD will give us glorious PCIe 4.0 speeds for less than the 250GB Samsung 980 Pro drive we used last month, making it a no-brainer, even if it won't perform quite as well as Samsung's pricier SSD. Meanwhile, we've taken our savings in the Intel build and converted it into storage, springing for the 500GB Crucial P1 M.2 drive.

AMD INGREDIENTS

PART			PRICE
Case	Corsair 4000D Airflow	NEW	$80
PSU	450W Gigabyte GP-450B 80+ Bronze		$40
Mobo	ASRock B550M Pro4		$74
CPU	AMD Ryzen 3 3100		$119
GPU	XFX Radeon RX 5500 XT 4GB	NEW	$148
RAM	16GB (2 x 8GB) G.Skill Ripjaws V Series @ 3,600MT/s	NEW	$54
SSD	500GB Gigabyte Aorus M.2 PCIe 4.0 SSD	NEW	$82
HDD	1TB Seagate Constellation ES ST1000NM0001 HDD		$30
OS	Windows 10 Home 64-bit OEM		$25
Approximate Price:			**$652**

INTEL INGREDIENTS

PART			PRICE
Case	Corsair 4000D Airflow	NEW	$80
PSU	450W Gigabyte GP-450B 80+ Bronze		$40
Mobo	ASRock B460M Pro4	NEW	$75
CPU	Intel Core i5-10400		$152
GPU	MSI GeForce GTX 1650 Super Ventus XS OC 4GB	NEW	$150
RAM	16GB (2 x 8GB) TeamGroup T-Force Dark Z @ 3,200MT/s	NEW	$50
SSD	500GB Crucial P1 M.2 PCIe 3.0 SSD	NEW	$45
HDD	1TB Seagate Constellation ES ST1000NM0001 HDD		$30
OS	Windows 10 Home 64-bit OEM		$25
Approximate Price:			**$647**

OUR NEW CASE for the mid-range builds is the PC011-Dynamic from Lian Li, a sleek dual-chambered chassis with tempered-glass windows and tons of space. Lian Li has always been a high-quality choice when it comes to PC cases, and the PC011-Dynamic is no exception. We've also got a new PSU for the Intel build, the MasterWatt 650, to provide a little choice when it comes to powering systems. Either power supply's fine for our builds here.

Both machines are getting a new cooler, the dual-fan A500 from Corsair (also seen in this issue's build feature). A last-minute price drop before going to print saw the A500 hit incredible value at just $53, almost half its initial $100 RRP. It's a beefy (but not too noisy) air cooler with swappable brackets that make it compatible with both AM4 and LGA 1200 CPU sockets. We looked into replacing the GPU these two machines share, but it's dropped in price since we last looked, and the next step up in performance would be to a pricier RTX 2060 Super or RX 5700 XT.

In the AMD machine, there's going to be a different processor sitting beneath that cooler. It's a very slight shift made to accommodate dwindling stock of the Ryzen 5 3600X at the time of writing, and we've gone for the cream-of-the-crop 3600XT. It actually costs less than the 3600X did last month, and while the performance difference is only between one and five percent in practical tests, it's definitely still the superior chip.

In our Intel build, we've got the same CPU but a new mobo: The MSI MPG Z490 Gaming Plus. It's a versatile and reasonably priced mobo, with USB-C Gen 3.2 and 2.5G LAN, and MSI's Mystic Light RGB lighting. Speaking of which, although the Trident Z RGB we used here last issue has leapt up in price, we don't want to leave you colorless. To retain lighting and performance with only a minor price increase, we've swapped it out for a 16GB kit of TeamGroup's T-Force Delta RGB memory, at the same 3,200MHz frequency.

AMD INGREDIENTS

PART			PRICE
Case	Lian Li PC011-Dynamic	NEW	$150
PSU	650W Corsair CX650		$69
Mobo	Asus TUF Gaming X570-Plus		$156
CPU	AMD Ryzen 5 3600XT	NEW	$236
Cooler	Corsair A500	NEW	$53
GPU	MSI Radeon RX 5700 MECH GP OC 8GB		$324
RAM	16GB (2 x 8GB) G.Skill Ripjaws V Series @ 3,600MT/s	NEW	$54
SSD	500GB Gigabyte Aorus Gen4 M.2 PCIe 4.0		$82
HDD	1TB Seagate Constellation ES ST1000NM0001 HDD		$30
OS	Windows 10 Home 64-bit OEM		$25
Approximate Price:			**$1,179**

INTEL INGREDIENTS

PART			PRICE
Case	Lian Li PC011-Dynamic	NEW	$150
PSU	650W Cooler Master MasterWatt 650	NEW	$68
Mobo	MSI MPG Z490 Gaming Plus	NEW	$170
CPU	Intel Core i7-10700		$324
Cooler	Corsair A500	NEW	$53
GPU	MSI Radeon RX 5700 MECH GP OC 8GB		$324
RAM	16GB (2 x 8GB) Team T-Force Delta RGB @ 3200	NEW	$75
SSD	500GB WD Black SN750 M.2 PCIe 3.0		$63
HDD	1TB Seagate Constellation ES ST1000NM0001 HDD		$30
OS	Windows 10 Home 64-bit OEM		$25
Approximate Price:			**$1,282**

TURBO

WOW, THAT'S ONE SERIOUS PRICE DROP on the i9-10900K! Best Buy came through for us here, with an awesome deal on this processor. With such a stonking saving for our Intel build, things are looking dicey for the AMD Turbo machine. We've splashed that extra scratch on the Intel system's mobo and cooler.

For the mobo, we've got the Asus TUF Gaming Z490-Plus WiFi, a gaming-oriented motherboard that uses Asus GameFirst VI, an AI-assisted feature that automatically optimizes network bandwidth usage to minimize lag spikes in online games. The new cooler is NZXT's excellent Kraken X63, a twin-fan AIO cooler with a seriously cool RGB-lit infinity mirror cap on the pump block.

The AMD system gets a new mobo too, from MSI: The X570 Gaming Pro Carbon WiFi. The other changes here are present in both builds, the reason for which will become clear as you read on.

First up is the memory. We found a fresh kit for the AMD build first, a 2x16GB Corsair Vengeance RGB Pro at 3,600MHz with slick RGB lighting. It's a solid choice for any high-end machine, and it's only $150—an absolute steal. It got us thinking: The Intel machine doesn't really need memory that fast, since only AMD chips benefit significantly from higher speeds due to how memory interacts with the Infinity Fabric in Ryzen chips. But why shouldn't we use that same kit in our Intel Turbo machine? It's excellent value and is sure to perform great. It's only marginally more expensive than a 3,200 or 3,000MHz kit, and works to better future-proof your PC as available memory speeds get faster and faster.

The other component that you can see here in both builds is, of course, the GPU. At the time of writing, RTX 3080 cards are still in high demand, and the only one we could find at a reasonable price was Gigabyte's Eagle model (again, thanks to Best Buy!) Hopefully by the time this issue is in your hands, stocks will have replenished somewhat, and those among you with their sights set on a major upgrade will be able to snap up one of these new cards. Or perhaps Radeon RX 6000 will be the next big thing...

AMD INGREDIENTS

PART		PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass **NEW**	$140
PSU	750W Corsair RM750x Modular PSU	$135
Mobo	MSI MPG X570 Gaming Pro Carbon WiFi **NEW**	$255
CPU	AMD Ryzen 9 3950X	$715
Cooler	Corsair iCUE H115i RGB Pro XT 280mm	$140
GPU	Gigabyte GeForce RTX 3080 Eagle 10G **NEW**	$730
RAM	32GB (2 x 16GB) Corsair Vengeance RGB Pro @ 3600MT/s **NEW**	$150
SSD	1TB FireCuda 520 M.2 PCIe 4.0 SSD **NEW**	$200
HDD	6TB Seagate BarraCuda ST6000DM003	$140
OS	Windows 10 Home 64-bit OEM	$25

Approximate Price: $2,630

INTEL INGREDIENTS

PART		PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass **NEW**	$140
PSU	850W NZXT C850	$140
Mobo	Asus TUF Gaming Z490-Plus WiFi **NEW**	$200
CPU	Intel Core i9-10900K	$530
Cooler	NZXT Kraken X63 280mm **NEW**	$151
GPU	Gigabyte GeForce RTX 3080 Eagle 10G **NEW**	$730
RAM	32GB (2 x 16GB) Corsair Vengeance RGB Pro @ 3600MT/s **NEW**	$150
SSD	1TB WD Black SN750 M.2 PCIe 3.0	$135
HDD	6TB Seagate BarraCuda ST6000DM003	$140
OS	Windows 10 Home 64-bit OEM	$25

Approximate Price: $2,341

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